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EPA-600/2-76-068a
March 1976

DEFENSE TECHNOLOGY FOR ENVIRONMENTAL PROTECTION

VOLUME I--FINAL REPORT

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MAY 19 1976
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by

Eldon A. Byrd, O.M. Meredith, and Sherman Gee

U.S. Naval Surface Weapons Center
White Oak
Silver Spring, Maryland 20910

EPA Interagency Agreement IAG-133-D
ROAP No. 21ADM-018
Program Element No. 1AB012

EPA Project Officer: James H. Abbott

Industrial Environmental Research Laboratory
Office of Energy, Minerals, and Industry
Research Triangle Park, NC 27711

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460

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DEFENSE TECHNOLOGY FOR ENVIRONMENTAL PROTECTION

Final Report

September 1973 - June 1975

by

Eldon A. Byrd, O. M. Meredith, and Sherman Gee

ABSTRACT

This report condenses an effort designed to identify and transfer significant technology concerned with air pollution monitoring and control technology from the Department of Defense (DOD) to the Environmental Protection Agency (EPA). Included are technology profiles of each DOD laboratory involved in particular work of interest to EPA Industrial Environmental Research Laboratory, a bibliography of pertinent DOD documentation, and a description and assessment of how the study was conducted.

This report is submitted in partial fulfillment of Interagency Agreement No. 133-D by the Naval Surface Weapons Center, White Oak under the sponsorship of EPA. Work was completed as of 30 June 1975.

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Acknowledgements

The cooperation of all laboratories surveyed was beyond expectation. The technology transfer personnel or surrogates within the laboratories were generally familiar with all technologies pertaining to pollution monitoring and control, and could lead us directly to the proper work areas.

Thanks are extended to Dr. William J. Yanta at the White Oak Laboratory for his cooperation in providing measurements of size distributions of particulates utilizing the White Oak laser doppler velocimeter, as reported in Appendix B.

The authors and the Naval Surface Weapons Center also wish to thank the EPA Industrial Environmental Research Laboratory - Research Triangle Park, especially A. B. Craig, James Abbott and Dr. Dennis Drehmel, for their valuable support.

Conclusions

The problems involved in protecting our environment are complex and inter-related. To be successfully solved, they must be subjected to a comprehensive attack which integrates a broad spectrum of technologies and which is oriented toward both short and long-range solutions.

The scope of environmental problems is so large that available resources of a sufficiently comprehensive nature are few. It must be recognized, also, that environmental problems are not solely technical in nature--social, economic, and political considerations are also of fundamental importance. In many instances, such non-technical factors will be paramount in the determination of how a particular problem is to be attacked. Clearly, therefore, effective solutions to environmental problems require a mutual appreciation--between scientists and technologists on the one hand and environmental decision makers on the other--of the capabilities and restraints under which each must operate.

Recommendation

Task 1 of IAG 133-D has demonstrated that techniques employed for the transfer of DOD technology to another government agency were successful; this project should serve as a model for similar projects, wherein a particular technology of interest to EPA within DOD can be accessed.

I. Executive Summary

A. Introduction

This report summarizes efforts to identify and transfer air pollution monitoring and control technology and related topics from the Department of Defense laboratories to the Environmental Protection Agency's (EPA) National Environmental Research Center, Research Triangle Park, North Carolina (NERC-RTP).*

Major impetus for this work developed from Mr. Harold Metcalf at the National Science Foundation (NSF) who in his capacity as Federal Laboratory Liaison Manager, sought to transfer technology from laboratories of the Department of Defense (DOD) Technology Transfer Consortium to the EPA. This initiative complemented earlier discussions between Dr. Sherman Gee, Head, Technology Transfer Office, Naval Surface Weapons Center (NAVSURFWPNCEN), White Oak Laboratory, and Dr. Dennis Drehmel, EPA NERC-RTP, concerning applicability of White Oak Laboratory technology to EPA air pollution problems. These developments eventually culminated in an interagency agreement (IAG) between NERC-RTP and the White Oak Laboratory as a member of the Consortium.

B. General Scope and Basic Approach

Twenty-seven laboratories were visited, and numerous scientists and engineers involved in relevant work were interviewed in order to establish a profile of laboratory capabilities. Documents were obtained from each facility to further identify technology and to expand the information base imparted in face to face contact.

Some 11,000 documents bearing on pollution technology were identified within DOD. Of these over 1,000 are cited in the bibliography of this report as being germane to air pollution monitoring and control, with emphasis on fine particulates.

This two-year effort concentrated upon fine particulates, but did not ignore other areas of air pollution technology when encountered.

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*Subsequent to 1 July 1975 the National Environmental Research Center changed its name to the Industrial Environmental Research Laboratory. Throughout this report, NERC will be used because all substantial effort was accomplished under that name.

C. Results

This summary report presents:

1. the technological profile of 27 laboratories engaged in air pollution projects (which provide a combined profile of DOD technological capability),

2. the transfer of "spin-off" bibliographies to various areas of EPA in addition to NERC-RTP,

3. the transfer of over 100 DOD documents and reports to NERC-RTP,

4. the establishment of closer direct contact between various DOD laboratories and NERC-RTP, which in some cases resulted in additional interagency agreements being established between the organizations, and

5. the transfer of several hardware items to NERC-RTP whose usefulless to DOD had come to an end, but whose value to the NERC is just commencing. This latter transfer of hardware has resulted in the savings of considerable taxpayer dollars (approximately $60,000).

Also, as part of Task 1 of this IAG, the dielectrophoretic concept for improved particulate filtering was explored by the Naval Research Laboratory. The details of this investigation can be found in Appendix B.

D. Conclusions

The completion of this task to transfer technology from DOD laboratories to EPA NERC-RTP on a systematic basis shows that a concerted effort is required to accelerate the flow of technical information and technology between federal agencies. Experiences gained and lessons learned in the course of this work could prove to be valuable in the structuring of future efforts to improve technology transfer among federal agencies. The results achieved suggest that an interagency arrangement of this type offers a workable and suitably focussed method by which DOD technologies could be brought to bear on specific problems and requirements in other federal civil agencies.

II. Program Framework

A. Introduction

Much of this nation's defense technology base can be adapted and transferred to meet many civilian priorities and requirements facing us today. Greater utilization of already-developed defense technology becomes increasingly important during inflationary times, where any contribution producing greater returns from the tax dollar is a step toward a strengthened economy. The nation's defense technology, found in the Department of Defense (DOD) can make multiple contributions. Hence, the DOD Technology Transfer Consortium was formed in 1971 to facilitate interservice information exchange, to help coordinate technology transfer activities among the military R&D centers and laboratories, and to facilitate liaison with potential technology users at the federal, state, and local government levels. More than 40 Army, Navy, and Air Force R&D centers and laboratories belonging to the Consortium have individual technology transfer functions. These functions constitute a geographically decentralized network of technology agents capable of assisting potential civilian users of military technology.

The adaptation and transfer of existing defense technology to civil sector requirements furthermore makes possible timely technological responses with avoidance of wasteful duplication of R&D efforts. In many instances, only the catalytic and relatively small effort to bridge the technology user-source gap is required.

NAVSURFWPNCEN (WOL), Silver Spring, Maryland, and EPA/NERC-RTP, following the Consortium concept, have developed an effective interagency liaison for accessibility to specific DOD technologies. NAVSURFWPNCEN effectively serves as central contact point for all DOD and AEC laboratories. NAVSURFWPNCEN's role is that of the "linker" or interface agent between EPA air pollution monitoring and control requirements and the available military technology. In addition, Defense Documentation Center (DDC) searches have been conducted by NAVSURFWPNCEN to determine the relevance of R&D results from past DOD sponsored programs.

B. Interagency Agreement (IAG)

The IAG consisted of the following tasks:

1. Identify and transfer available defense technology applicable to EPA particulate control studies.

2. Design and fabricate a mobile particulate emissions control test facility.

3. Design and fabricate a standardized flow source for particulate testing.

The objectives of Task 1, above, were to:

1. Identify existing technologies and capabilities in DOD laboratories relating to particulate control.

2. Develop a bibliography of information within DOD which could be applied to particulate control.

3. Assess the feasibility of DOD technology for collecting particulates, especially fine particles.

4. Develop technical-managerial procedures for transfering identified technologies useful to EPA.

5. Transfer from DOD to EPA identified technology applicable to fin particulate control.

This report details the effort expended in the accomplishment of Task 1 only; Task 2 has been reported on separately by NAVSURFWPNCEN Dahlgren, and Task 3 has been cancelled.

C. Management System

Task 1 was viewed as an experimental pilot program. It was decided that NAVSURFWPNCEN (White Oak Laboratory)* would not become involved with the management or performance of Task 2. NAVSURFWPNCEN (WOL) was to concentrate only on the DOD-EPA liaison and technology applicable to NERC-RTP requirements. However, NAVSURFWPNCEN (WOL) did initiate and coordinate initial contacts between several DOD laboratories and NERC-RTP which eventually led to the awarding of Task 2 to NAVSURFWPNCEN, Dahlgren Laboratory[t] (DL).

During the performance of Task 1, the DOD and non-DOD laboratories shown in Table II-1 were visited.

---

*Formerly Naval Ordnance Laboratory

[t] Formerly Naval Weapons Laboratory (NWL), Dahlgren, Va. The selection of NWL for Task 2 predates the subsequent merger of the laboratory with the Naval Ordnance Laboratory to form the Naval Surface Weapons Center.

Table II-1

LABORATORIES VISITED IN CONNECTION WITH IAG 133D

Date	Laboratory	Location
16 Nov 1973	Naval Undersea Center (NUC)	San Diego, CA
16 Nov 1973	Naval Electronics Laboratory (NELC)	San Diego, CA
19 Nov 1973	Naval Weapons Center	China Lake, CA
14 Jan 1974	Naval Weapons Laboratory (NWL)	Dahlgren, VA
15 Jan 1974	Naval Ordnance Laboratory (NOL)	White Oak, MD
15 Jan 1974	Naval Research Laboratory (NRL)	Washington, DC
16 Jan 1974	Army Land Warfare Laboratory (ALWL)	Aberdeen, MD
17 Jan 1974	Army Edgewood Arsenal	Aberdeen, MD
18 Jan 1974	Naval Ship Research & Development Lab	Annapolis, MD
22 Feb 1974	Naval Missile Center (NMC)	Pt. Mugu, CA
25 Feb 1974	Lawrence Berkeley Laboratory (LBL) (AEC)	Berkeley, CA
27 Feb 1974	Naval Postgraduate School (NPGS)	Monterey, CA
27-28 Mar 1974	Dugway Proving Grounds (DPG)	Dugway, UT
29 May 1974	Air Force Weapons Laboratory (AFWL)	Albuquerque, NM
30 May 1974	Army White Sands Missile Range	White Sands, NM
31 May 1974	Los Alamos Scientific Laboratory (LASL) (AEC)	Los Alamos, NM
9 Jul 1974	Lawrence Livermore Laboratory (LLL) (AEC)	Livermore, CA
10 Jul 1974	Lawrence Berkeley Laboratory (LBL) (AEC)	

	(return visit)	Berkeley, CA
11 Jul 1974	McClellan Air Force Base (stack emissions)	Sacramento, CA
7 Aug 1974	Army Civil Engineering Laboratory (ACEL)	Champaign, IL
8 Aug 1974	Wright-Patterson Air Force Base (W-P AFB)	Dayton, OH
11 Sep 1974	Army Cold Regions Research & Engineering Laboratory (ACRREL)	Hanover, NH
12 Sep 1974	Rome Air Development Center (RADC)	Griffiss Air Force Base NY
3 Dec 1974	Air Force Rocket Propulsion Laboratory (AFRPL)	Edwards AFB, CA
4 Dec 1974	Air Force Weapons Laboratory (AFWL) (return visit)	Albuquerque, NM
5 Dec 1974	Sandia Laboratories (AEC)	Sandia, NM
7 Jan 1975	Desert Research Institute (University of Nevada)	Reno, NV
8 Jan 1975	Naval Biomedical Research Laboratory (NBRL)	Oakland, CA
9 Jan 1975	Naval Vector Disease Control and Ecology Center	Alameda, CA

III. DOD Laboratories Technology Survey

A. Approach

The first effort was to visit EPA-NERC/RTP for familiarization with requirements in air pollution monitoring and control, especially concerning particulates. Information gained on EPA requirements was transmitted by letter to appropriate DOD laboratories (see listing in Table III-1).

Table III-1

LIST OF INITIAL NERC-RTP REQUIREMENTS.

Particle size distribution (2 to .10 microns)
Techniques for aerosol generation
Aerosol physics
Particulate sensing and measurement
Mass flow (low velocity)
Flow streams
Automated sensing techniques and instrumentation
Chemical characterization of particles
Microanalysis of particulates from small sample sizes (1/2 to 1 μgm.)
Elemental analysis of collected particles
Measurement techniques for SO_2, SO_4, NO_2, etc.
Turbulence of low velocity gas flows
Volumetric flow
Gaseous and particulate mixtures -- sensing and analysis by lasers or other means
Remote analysis of stack gas (analogous with remote analysis of missile plumes)
Precipitators, scrubbers, and filters
New and novel precipitation techniques (e.g., sonic aglomerators)
Fibrous filters (excluding disposable mat-type filters) and their characteristics
Cleanable woven and nonwoven filters
High velocity filtration
High temperature filtration (greater than 550°F)
Fine (less than 2 microns) filtration
High efficiency - high flow filters
Filtration theory and models
Efficiency vs particle size characterization of filters
Dust characteristics (density, distribution, hardness, etc.)
Dust generation and redispersion

Later, this list was expanded to include virtually all technologies relating to air pollution monitoring and control, including water to air intermedia considerations. The EPA/NERC-RTP organization, programs, and requirements were presented also by A. B. Craig, J. H. Abbott, and Dr. Dennis Drehmel of EPA at the DOD Technology Transfer Consortium Meeting in San Diego, during 13-16 November 1973.

B. Conferences and Symposia Attended

To expand their background in air pollution problems, representatives from NAVSURFWPNCEN (WOL) have attended EPA-sponsored technical meetings including: the 2nd Joint Conference on Sensing Environmental Pollutants, December 1973 (Washington, D.C.); National Oceanographic Institute Center (NOIC) Turbidity Workshop, 6-8 May 1974 (Washington, D.C.); the National Conference on Municipal Sludge Management, 11-13 June 1974 (Pittsburgh, PA); the Interservice Environmental Quality Conference 17-19 September 1974 (Annapolis, MD); and the Seventh Annual Aerosol Technology Meeting 10-11 October (Chicago, IL). Also, papers on aerosol technology by Eldon Byrd, Sherman Gee and O. M. Meredith of NAVSURFWPNCEN (WOL) were presented at the 68th Annual Meeting of the Air Pollution Control Association (APCA) 15-20 June 1975 (Boston, MA) and the Intersociety Conference on Environmental Systems, 21-24 July 1975 (San Francisco, CA). The APCA paper was presented in absentia by Major Peter Crowley of the Air Force Weapons Center, Kirtland Air Force Base, Albuquerque, NM.

C. Results

1. Laboratories Visited

All DOD (and later) Atomic Energy Commission (AEC), now Energy Research and Development Administration (ERDA) laboratories were first identified and grouped according to geographical location for minimizing subsequent travel expenses. If initial contact with a particular laboratory revealed current or past efforts in air pollution related technologies, a facility visit was arranged for NERC-RTP and NAVSURFWPNCEN (WOL) representatives. Agendas were prepared to insure efficient use of time during each visit.

Interviews with scientists and engineers involved in air-pollution related monitoring and control technologies were conducted at each facility visited. From these interviews and acquired documents, technology capability profiles were developed for each laboratory (see Appendix A). After a few laboratory visits it became apparent that a great deal more in the way of technology was available than had been anticipated. Technological developments in the areas of gaseous pollutants, solid waste disposal, and liquid wastes relating to air pollution were impossible to ignore. The IAG was accordingly modified to include all areas of pollution of interest to NERC-RTP laboratories in addition to the Control Systems Laboratory.

Besides the laboratory visits listed in Table II-1, trips were made to NERC-RTP on 28-31 August 1973 and 28-29 January 1975, NERC-Cincinnati on 21 October 1974, and NERC-Corvalis in 22 Oct 1974 by NAVSURFWPNCEN (WOL) personnel.

Visits scheduled for the following laboratories were waived because of funding limitations imposed by NERC-RTP.

Army Natick Laboratories	Natick, MA
Brookhaven National Laboratory	Upton, NY
Army Picatinny Arsenal	Dover, NJ

Nevertheless, most DOD laboratories involved in air pollution monitoring and control efforts were visited.

2. DOD-EPA Linker Function

The role of NAVSURFWPNCEN (WOL) to act as central liaison effected a substantial decrease in the need for NERC-RTP interaction with DOD laboratories on an individual basis. It was found, however, that several DOD laboratories had established contact with NERC-RTP prior to the establishment of the agreement. These contacts were encouraged to continue and additional direct interaction between DOD laboratories and NERC were established. For example, an IAG was worked out between NWC, China Lake, and NERC-RTP as a result of a visit made as part of this effort. Also, the visit to Edgewood Arsenal was a contributing factor in the finalization of an IAG, even though negotiations between Edgewood and NERC-RTP had commenced before the visit.

3. Technology Transfered

Hardware

During laboratory visits several items no longer needed by DOD but useful to EPA NERC-RTP were discovered. Specifically, the Army Land Warfare Laboratory in Aberdeen, Maryland made available a General Electric particle generator, a GE condensate nuclei counter (CNC), and a Nolan standard CNC. The Naval Missile Center at Pt. Mugu, California had a TiO_2 aerosol generator left over from an optical chaff project. NAVSURFWPNCEN (WOL) made the necessary arrangements and had all the above equipment shipped to NERC-RTP. This transfer involved many thousands of dollars worth of equipment which had served its DOD purpose, but promised to be of use to EPA.

Documents

The technology document search effort included the following:

1. Defense Documentation Center (DDC)

2. NASA-related literature

3. Army, Air Force, and Navy libraries

4. Miscellaneous other report sources.

Search terms relating to air pollution monitoring and control were input into computer search systems such as that maintained by DDC. An initial screening revealed tremendous numbers of documents that had air pollution in the title or mentioned in the text. Consequently, subsearches were initiated based on the intersection of two or more technologies to retrieve most relevant documents. Similar procedures were used for determining water pollution and solid waste disposal impact on air pollution. Well over a hundred hard copy DOD/National Laboratory reports have been turned over to NERC-RTP. Many of these reports were obtained during laboratory visits. All were routed to NERC personnel who had expressed interest in specific subject matter relating to Task 1.

Bibliographies

Appendix C contains the bibliographies selected for inclusion in this report. All citations are grouped according to the NERC-RTP organizational structure (circa spring of 1975). This grouping facilitates usage by interested NERC personnel.

Details on the development of DDC bibliographies are found in Section IV.

The DDC catalog contains 730,000 abstracts. Almost 500 specific search terms were used to generate approximately 90 bibliographies. The average number of documents cited in each bibliography was 240; therefore, a total of approximately 21,600 documents were initially identified. A spot check revealed about a 50% redundancy factor (i.e., each document is cited about twice). Therefore, more than 10,000 actual documents were uncovered in DDC alone that are of value to the EPA. This final report lists approximately 1,000 reports germane to air pollution monitoring and control technology.

IV. Defense Documentation Center (DDC) Computer Search

A. Objective

This effort has sought the effective utilization of existing research and development information as partial fulfillment of the interagency agreement. While air pollution has been the assigned topic, opportunities to use the DDC data-base for other environmental protection topics have been exploited wherever possible.

B. Background

The Resource

In recent years all technical reports issued by DOD laboratories or defense contractors have been accumulated by the DDC which constitutes a primary bibliographic resource of about 730,000 past research, development, test, and evaluation efforts. The reports are assigned an AD (Accessioned Document) number for announcement, retrieval and request purposes and they are categorized into a two level arrangement consisting of 22 major subject fields, with a further subdivision of 188 related subject groups. Those reports which are unclassified and unlimited in distribution are passed on to the National Technical Information Service (NTIS) of the U. S. Department of Commerce for distribution and sale, while the restricted documents are retained in the DDC data base. The information of the data base can be rapidly and efficiently accessed via a computer controlled data retrieval system (Defense RDT&E On-Line System) from a remote terminal such as one located in the technical library of NAVSURFWPNCEN, (WOL). For extensive bibliographic searches of the entire data base, requests are relayed to the main DDC computer complex. Output information is available in cathode ray tube (CRT) display,s at remote terminals, as printouts prepared automatically from CRT display, or as bound documents prepared by DDC.

For this effort, a technical vocabulary prepared by DDC has provided a comprehensive source of search terms useful for retrieving technical reports. The "Defense Retrieval and Indexing Terminology (DRIT)" is a natural language (English) technical vocabulary compiled by extracting author terminology from technical summaries, titles and abstracts accummulated by DDC.

C. Approach

The singular path toward reaching search goals through use of the DDC technical report files requires an intermediate identification of search terms. Three methods have been implemented:

1. persual of a DDC thesaurus for prominent environmentally related posting terms;

2. consultation with investigators and administrators in the environmental protection areas or attendance at technical meetings and

3. use of reference sources.

Use of the DDC Thesaurus

The DRIT which has been described above is the first source of terms for use in the retrieval of specific information from the DDC technical report file. Usually this document aids literature retrieval since there is a limited set of indexing terms which might relate to specific subject areas. With the present effort the document has been searched extensively with two objectives in mind:

1. to find information wherever it may occur on air pollution and

2. to collect as spinoff as much bibliographic information as may be available related to various aspects of environmental protection.

A listing of indexing terms selected for extended information retrieval is presented in Table IV-1.

A summary of contacts established and meetings attended appear in Table IV-2.

Table IV-1

DDC LITERATURE SEARCH TOPICS ATTEMPTED

Acetaldehyde

Acetaldehyde Air Pollution

Acetaldehyde Water Pollution

Acetic Acid

Acetic Acid Air Pollution

Acetic Acid Odors

Acetic Acid Water Pollution

Acrylonitrile

Acrylonitrile Air Pollution

Acrylonitrile Odors

Acrylonitrile Water Pollution

Activated Sludge Pilot Facility

Acitvated Sludge Process

Activated Sludge Secondary Treatment

Adverse Environmental Conditions

Aerosol Assessment

Aerosol Chemical Characteristics

Aerosol Filters

Aerosol Fine Structure

Aerosol Forming Techniques

Aerosol Generation From Gases

Aerosol Generators

Aerosol Micro-organisms

Aerosol Monitoring

Aerosol Particle Size Distributions

Aerosol Penetration

Aerosol Sulfur Dioxide Interactions

Aerosols (General)

Agent Environmental Interactions

Air Pollution Abatement

Air Pollution Control

Air Pollution Epidemiology

Air Pollution Fallout

Air Pollution Measurement

Air Pollution Simulation

Air Pollution Surveys

Air Quality Assessment Models

Air Quality Monitoring Networks

Airborne Micro-organisms

Alcohol

Alcohol Air Pollution

Alcohol Odors

Alcohol Water Pollution

Aldrin

Aldrin Air Pollution

Aldrin Odors

Aldrin Water Pollution

Alkyl Resin

Alkyl Resin Air Pollution

Alkyl Resin Odors

Ambient Environmental Stresses

Ammonia Odors

Amyl Acetate

Army Wastewater Treatment Facilities

Artificial Precipitation

Asbestos Chemical Structure

Asphalt Manufacturing

Asphalt Manufacturing Air Pollution

Asphalt Manufacturing Odors

Asphalt Manufacturing Plants

Atmospheric Diffusion

Atmospheric Models

Atmospheric Ozone

Atmospheric Pollutant

Atmospheric Transport

Biological Aerosols

Biological Agent Aerosol Particles

Blast Furnace Gas Washwater

Breweries

Butanol

Butanol Air Pollution

Butanol Odors

Butanol Water Pollution

Butyl Mercaptan

Butylamine Air Pollution

Butylamine Water Pollution

Butyric Acid

Carbon Tetrachloride

Carbon Tetrachloride Air Pollution

Carbon Tetrachloride Odors

Carbon Tetrachloride Water Pollution

Carbonyl Chloride

Chemical Agent Disposal

Chemical Analysis of Asbestos

Chemical Analysis of Particulates

Chemical Collection of Aerosols

Chemical Contamination

Chemical Detection of Asbestos

Chemical Emissions

Chemical Plants

Citrus Processing

Citrus Processing Air Pollution

Citrus Processing Odors

City Wastes

City Wastewater

Clean Environment

Cloud Seeding

Coastal Environmental Data

Coffee Roasting

Coffee Roasting Air Pollution

Coffee Roasting Odor

Coke

Coke Air Pollution

Coke Odors

Commode Waste Treatment

Community Air Quality

Contaminant Concentration

Contaminant Control

Contaminant Control Equipment

Contaminated Air

Contaminated Soil

Contamination Levels

Contamination Monitors

Contamination Preventive Treatment

Contamination Protection

Control Air Pollution

Conversion of Sulfur Dioxide Aerosols

Cyanide

Cyanide Air Pollution

Cyanide Water Pollution

Decontaminated Soil

Diallylsulfide

Dibutylamine Air Pollution

Dibutylamine Water Pollution

Dichloro-Diphenyl-Trichloroethane (DDT)

Dichloro-Diphenyl-Trichloroethane (DDT) Air Pollution

Dichloro-Diphenyl-Trichloroethane (DDT) Odors

Dichloro-Diphenyl-Trichloroethane (DDT) Water Pollution

Dichlorophenol

Dieldrin

Dieldrin Air Pollution

Dieldrin Odors

Dieldrin Water Pollution

Diisobutylamine

Diisopropylamine

Dimethoat

Dimethyl Sulfide

Dust Control Material

Dust Damage

Dust Environment

Dust Erosion

Dust Model

Dust Particles

Dust Particulates

Dust Problems

Dustborne Microbial Aerosols

Dusty Atmospheres

Ecological Hazards

Ecology

Effluent Air Pollution Control Equipment

Engine Emissions

Enteric Viruses

Environmental Assessment

Environmental Contaminants

Environmental Contamination

Environmental Control

Environmental Corrections

Environmental Degradation

Environmental Deterioration

Environmental Deterioration Prevention

Environmental Exposure

Environmental Hazards

Environmental Health

Environmental Health Engineering

Environmental Hygiene

Environmental Interactions

Environmental Measurement Techniques

Environmental Mechanical Protection

Environmental Microbiology

Environmental Model

Environmental Pollution Control

Environmental Pollution Problems

Environmental Prediction Problems

Environmental Problems

Environmental Profiles

Environmental Protection

Environmental Protection Materials

Environmental Requirements

Environmental Research Support

Environmental Resistance

Environmental Response Data

Environmental Sensitivity

Environmental Monitor Sensors

Environmental Signature

Environmental Stability

Environmental Support Studies

Environmental Surveillance Tests

Environmental Variables

Environmental Vulnerability

Ethyl Acrylate

Ethylamine Air Pollution

Ethylamine Water Pollution

Explosive Ordnance Disposal

Fatty Acids

Fatty Acid Air Pollution

Fatty Acid Odors

Fatty Acid Water Pollution

Fermentation Industry

Fertilizer Plants

Fish Kill

Fish Packing

Fluorine Compounds

Fluorine Compounds in Air Pollution

Fluorine Compound Odors

Fluorine Vapors

Flow Activated Sludge Units

Formaldehyde

Formaldehyde Air Pollution

Formaldehyde Odors

Formaldehyde Water Pollution

Foundries

Fungicides

Gas Scrubbers and Water Pollution

Grease Factories

Hydrocarbon

Hydrocarbon Air Pollution

Hydrocarbon Water Pollution

Hydrogen Chloride

Hydrogen Chloride Air Pollution

Hydrogen Sulfide

Hydrogen Sulfide Air Pollution

Heptachlor

Heptachlor Air Pollution

Heptachlor Odors

Heptachlor Water Pollution

Heptane

Heptane Air Pollution

Heptane Odors

Heptane Water Pollution

Herbicides

Hexylamine Air Pollution

Hexylamine Water Pollution

Industrial Pollution Sources

Insecticides

Interlaboratory Certification

Interlaboratory Testing

Iron Refining

Isobutyric Acid Air Pollution

Isobutyric Acid Water Pollution

Isoparaffins

Isopropanol

Kerosene

Laboratory Certification

Laboratory Testing

Laboratory Verification

Laser Holography

Lindane

Lindane Air Pollution

Lindane Odors

Lindane Water Pollution

Longterm Health Effects

Malathion

Melathion Air Pollution

Malathion Odors

Malathion Water Pollution

Maleic Anhydride

Maleic Anhydride Air Pollution

Maleic Anhydride Odors

Man Environment Systems

Meat Packing

Mercaptans

Mercaptan Air Pollution

Mercaptan Odors

Mercaptan Water Pollution

Metal Poisoning

Meteorological Simulation

Methane Air Pollution

Methane Water Pollution

Methanol

Methanol Air Pollution

Methanol Odors

Methanol Water Pollution

Methoxychlor

Methyl Mercaptan

Microbial Contamination

Microbiologic Hazards

Microbiological Health Hazards

Micrometeorology

Military Environmental Health Problems

Mixed Activated Sludge Reactors

Mobile Pollution

Moisture Monitor

Molluscacides

Naphthalene

Naphthalene Air Pollution

Naphthalene Odors

Naphthalene Water Pollution

Naphthenes

Naval Ecology

Naval Environmental Problems

Navy Pollutants
Navy Pollution Problems
Navy Sanitary Waste Treatment Program
Navy Toxicology
Nondestructive Testing
Nonsanitary Military Wastes
Nonane
Noxious Fumes
Ocean Environment
Ocean Pollution
Octane
Octane Air Pollution
Octane Odors
Octane Water Pollution
Octyl Alcohol
Odor
Oil Refining and Air Pollution
Organic Pollutants
Organic Sulfur Compounds
Organic Sulfur Compounds in Air Pollution
Organic Sulfur Compounds Odors
Oxidizer Particle Size
Ozone at Low Altitudes
Ozone Density

Ozone Distributions
Paint Solvents
Paper Mills
Parathion
Parathion Air Pollution
Parathion Odors
Parathion Water Pollution
Particle Size
Particle Size Classification
Particulate Air Pollutants
Particulate Materials
Particulate Sampling
Particulate Toxicity
Pathogen Aerosols
Pesticide Containers
Pesticide Disposal
Pesticide Distributors
Pesticide Formulations
Pesticide Particles
Pesticide Residues
Pesticide Wastes
Pesticides Inventory
Phenol
Phenol Odors
Pickling Solutions
Plant Acids

Plant Acid Air Pollution

Plant Acid and Water Pollution

Plant Acid Odors

Plastic Plants

Plastic Plants and Air Pollution

Plastic Plant Odors

Polluted Surface Water

Pollution Abatement

Pollution Abatement Control

Pollution Abatement Pilot Facility

Pollution Control

Pollution Control Phase

Pollution Control Systems

Pollution Elimination

Pollution Emissions

Pollution Gas

Pollution Gas Detectors

Pollution Level

Pollution Monitoring

Pollution Samples

Pollution Sources

Pollution Standards

Pollution Transport

Pollution Transport Cycles

Precipitation Scavenging

Propanol

Proprionaldehyde

Proprionic Acid

Pyridine

Pyridine Bases

Pyridine Base Water Pollution

Quality Assurance Documents

Quality Assurance Maintenance

Quality Assurance Models

Quality Assurance Standards

Quality Control Distribution

Quality Control Handbooks

Quality Control Legislation

Quality Control Methodology

Quality Control Methods

Quality Control Organizations

Quality Control Personnel

Quality Control Regulations

Quality Control Specifications

Quality Control Standards

Quality Control Systems

Quality Control Textbooks

Quality Control of Air Pollution Detectors

Rainout

Remote Base Waste Management

Rendering

Residual Contamination

Rodenticides

Rubber Tire Production

Sanitary Landfills

Scrubbers

Secondary Toxic Hazards

Shipboard Air Pollution Control Devices

Shipboard Toxic Vapor Detection

Simulated Environment

Simulated Liquid Wastes

Single Environmental Stresses

Skatol

Slaughter Houses

Smoke Abatement

Smoke Control

Smoke Pollution

Soap Factories

Soda Pulp

Soda Pulp Air Pollution

Soda Pulp Odors

Soda Pulp Water Pollution

Solar Radiation Intensity

Stack Emissions

Steel Manufacturing

Styrene Odors

Sugar Refineries

Sugar Refinery Air Pollution

Sugar Refinery Odors

Sugar Refinery Water Pollution

Sulfide

Sulfide Air Pollution

Sulfide Odors

Sulfide Water Pollution

Sulfite Pulp

Sulfite Pulp Air Pollution

Sulfite Pulp Odors

Sulfite Pulp Water Pollution

Sunlight

Surface Dust

Temperate Ecosystems

Textile Industry

Textile Industry Air Pollution

Textile Industry Odors

Textile Industry Water Pollution

Thiol Odors

Toxaphen

Toxic Air Pollutants

Toxic Concentrations

Toxic Contaminants

Toxic Decontaminants

Toxic Environments

Toxic Exposures

Toxic Hazards Research

Toxic Materials

Toxicological Information

Trichloroethylene

Trichloroethylene Air Pollution

Trichloroethylene Odors

Trichloroethylene Water Pollution

Triethylamine Air Pollution

Triethylamine Water Pollution

Trimethylamine

Tropical Ecosystems

Uniform Sized Aerosol Particles

Vapor Aerosol

Vapor Hazards

Varied Environments

Vehicle Exhausts

Viral Aerosols

Viral Agents

Viral Penetration

Virus Particles

Volatile Irritants

Waste Control

Waste Decontaminants

Waste Elimination

Waste Munitions

Waste Streams

Waste Treatment

Wastes (Sanitary Engineering)

Wastewater Discharges

Wastewater Sampling

Wastewater Treatment

Water Contamination

Water Pollution Control

Water Pollution Problem Areas

Water Quality Problems

Water Scrubbing

Wildlife Ecology

Wood Charcoal

Xanthate Process

Table IV-2

COMMUNICATIONS WITH ENVIRONMENTAL PROTECTION SPECIALISTS

A. Meetings Attended

Workshops and the Application of Pollution Abatement Technology to the Local Governments, Annapolis, Maryland, 16 October 1975

National Oceanographic Instrumentation Center Turbidity Workshop, Washington, D. C., 6-8 May 1974

National Conference on Municipal Sludge Management, 11-13 June 1974, Pittsburgh, Pennsylvania

National Conference on Management and Disposal of Residues from the Treatment of Industrial Wastewaters, Washington, D. C., 3-5 February 1975

B. Personal Contacts

J. B. Anderson
Methods Development and Quality Assurance Research Lab
NERC - Cincinnati, Ohio

Dwight Ballenger
Methods Development and Quality Assurance Research Laboratory
NERC - Cincinnati, Ohio

James R. Boydston
Industrial Wastes Branch
Pacific Northwest Environmental Research Laboratory
NERC - Corvallis, Oregon

John O. Burckle
Solid and Hazardous Waste Reserach Laboratory
NERC - Cincinnati, Ohio

Charles R. Hosler
Meteorology Laboratory
NERC - Research Triangle Park, North Carolina

Norbert A. Jaworski
Pacific Northwest Environmental Research Laboratory
NERC - Corvallis, Oregon

Earl Kari
Deputy Director
NERC - Corvallis, Oregon

William Loey
Industrial Pollution Control Division
Office of Research and Development
EPA - Washington, D. C.

Darryl von Lehmden
Quality Assurance Laboratory
NERC - Research Triangle Park

Thomas Murphy
Non-Point Pollution Control Division
Office of Research and Development
EPA - Washington, D. C.

Larry Raniere
Ecological Sciences Branch
NERC - Corvallis, Oregon

Roy Resnick
Standards Divison
Occupational Safety and Health Administration (OSHA)
Washington, D. C.

George Rey
Industrial Pollution Control Division
Office of Research and Development
EPA - Washington, D. C.

Charles Ris
Industrial Pollution Control Division
Office of Research and Development
EPA - Washington, D. C.

William Rosenkranz
Municipal Pollution Control Division
Office of Research and Development
EPA - Washington, D. C.

Paul Des Rosiers
Industrial Pollution Control Division
Office of Research and Development
EPA - Washington, D. C.

R. D. Shull
Washington Environmental Research Center
EPA - Washington, D. C.

James Smith
Solid and Hazardous Waste Research Laboratory
NERC - Cincinnati, Ohio

Robert L. Stenburg
Solid and Hazardous Waste Research Laboratory
NERC - Cincinnati, Ohio

Richard Tabakin
Industrial Waste Technology Branch
Edison Water Quality Research Laboratory
NERC - Edison, New Jersey

A. W. Thomas
Hazards Surveillance Branch
National Institute of Occupational Safety and Health (NIOSH)
Control Disease Center, HEW
Rockville, Maryland

Edy Tompkins
NERC - Research Triangle Park, North Carolina

Frank Wilkes
Biological Processes and Effects Division
Office of Research and Development
EPA - Washington, D. C.

E. Results

The approach for developing DDC bibliographies started with identification of all retrieval terms, related even in the remotest sense to environmental protection, in DRIT. Two topics, oil pollution and radioactive contamination were rejected, however, because extensive technology transfer had been achieved already in those areas.

Then, a systematic search via remote on-line computer terminal probed the DDC technical reports file* to isolate information accessible with individual retrieval terms. The set of report titles presented for an individual retrieval term were scanned to:

1. identify reports concerning the basic objective and

2. determine the relevancy of an overall set of titles to environmental protection. Individual reports relating to the basic objective were printed out at the terminal. A set of titles showing definite relevance to environmental protection were ordered as a unclassified "spin-off" bibliography for subsequent release to interested persons.

The broad scope of the literature search forced adoption of some restrictions upon the number of "spin-off" bibliographies produced. A rationale was developed which appeared to meet the needs of the situation. If a majority of titles listed under a particular retrieval term appeared pertinent to some environmental protection topic, a bibliography was ordered. If a minor portion in a set of titles was relevant. the area was passed over with the assumption that the information would be picked up later with a more representative search term. In practice a redundancy of the data base created by cross referencing practices of DDC ought to cause recovery of large amounts of information under various retrieval terms. An example is presented here to demonstrate the redundancies encountered in an early search.

A search was mounted to acquire DDC information related to municipal waste pollution technology. The results of that effort, presented in Table IV-3, indicate significant numbers of "finds" or technical report abstracts isolated for each of several search terms. This total collection of "finds" was analyzed then for redundancies and pertinent results are shown in Table IV-4. The percentage of redundancy can be stated here as 147/294 x 100 or 50%. Although this analysis is not a vigorous proof, it appears, nevertheless, as a reasonable basis for the rationale employed here.

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*In the instance of a specific request the work unit and work plan files were surveyed.

Table IV-3

SEARCH RESULTS ON MUNICIPAL WASTES POLLUTION CONTROL TECHNOLOGY TOPICS

Topic (retrival term)	Number of "finds"*
Wastewater treatment	72
Wastes (sanitary engineering)	8[illegible]
Sewage	100
Municipal Wastes	88
Sludge	20
Pasteurization	1
Total "finds"	294

*A "find" is a single technical report title and abstract listed under an individual retrieval term

Table IV-4

REDUNDANCY IN COMBINED BIBLIOGRAPHIES ON MUNICIPAL WASTES POLLUTION CONTROL TECHNOLOGY

Type of Replications	Number of Instances	Number of Replicates Subtotal
Single	44	44
Double	30	60
Triple	13	39
Quadruple	1	4
Total number of replicates		147

$$\text{Percent redundancy} = \frac{147 \times 100}{294} = 50\%$$

Bibliographies Accomplished

A summary of the bibliographies generated is presented in Table IV-5 while abstracts of technical reports related to the main topic are being presented in a separate volume.

Statistically speaking, the DDC resource available for searching contains approximately 730,000 abstracts. About 480 specific search terms or "strategies" were used and 91 completed bibliographies resulted. The average number of abstracts per completed bibliography was 240 while the actual values ranged from 1 to 1980 abstracts.

Table IV-5

SUMMARY OF BIBLIOGRAPHIES GENERATED FROM SEARCHES OF DDC FILES

Search Topic	Number of Finds	Distribution of Bibliography
Acetic Acid -Air Pollution -Odors -Water Pollution	10	WAIT*
Aerosol Chemical Properties	42	NERC-RTP
Aerosol Fine Structure	500	NERC-RTP
Aerosol Gas Generators	25	NERC-RTP
Aerosol Particle Size Distribution	267	PTS**
Air Cleaners and Air Filters	559	PTS
Air Pollution -Abatement -Control -Fallout -Surveys	1817	PTS
Air Pollution Simulation	37	NERC-RTP (Charles R. Hosler)
Air Pollution Epidemiology	6	NERC-RTP
Air/Water Pollution		WAIT

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* Water to Air Intermedia Transport (WAIT)
** Particulate Technology Study (PTS)

Airborne and Aerosol Microorganisms	149	PTS
Aldrin Water Pollution	2	WAIT
Ammunition Hazards	64	NERC-Edison, NJ (R. Tabakin)
Ammunition Plants	50	NERC-Edison, NJ (R. Tabakin)
Asbestos	603	NERC-RTP (Dennis C. Drehmel)
Asphalt Manufacturing Air Pollution	1	WAIT
Atmospheric Pollutants	154	PTS, WAIT
Beryllium	1980	NERC-RTP (Dennis C. Drehmel)
Biological Aerosols	34	WAIT, PTS
Carbon Tetrachloride -Air Pollution -Odors -Water Pollution	4	WAIT
Chemical Agent/Explosive Ordnance Disposal	7	NERC-Edison, NJ (R. Tabakin)
Control Air Pollution	1625	PTS
Cyanide Water Pollution	12	WAIT
Dieldrin Water Pollution	3	WAIT
Diethyl-Dichloro-Triphenylethane (DDT) -Air Pollution -Odors -Water Pollution	18	WAIT
Dust Particles and Particulates	175	PTS
Dusty Atmospheres	70	PTS
Emission Topics (Selected) -Emission & Control	69	PTS

-Exhaust Emissions -Pollution Emissions -Smoke Production -Stack Emissions		
Environmental Topics (Selected) -Contamination -Corrections -Degradation -Hygiene -Pollution Problems	346	WAIT
Estuarine Circulation	28	NAVSURFWPNCEN
Environmental Monitor Sensors	12	NAVSURFWPNCEN
Environmental Health	39	WAIT
Fatty Acids -Air Pollution -Odors -Water Pollution	12	WAIT
Formaldehyde -Air Pollution -Odors	14	WAIT
Heptachlor Water Pollution	2	WAIT
Hydrogen Chloride Air Pollution	8	WAIT
Hydrogen Sulfide Air Pollution	24	WAIT
Hydrocarbon Water Pollution	46	WAIT
Incinerators (Selected)	22	EPA-Wash. D.C. (Wm. Rosenkrantz) (R. G. Shull)
Industrial Wastes	476	WAIT
Instrumented Sonobuoys	28	NAVSURFWPNCEN
Laser Holography		NERC-RTP (William Wilson)

Lindane Water Pollution	1	WAIT
Malathion Water Pollution	4	WAIT
Mercury	1213	NERC-RTP (Dennis C. Drehmel)
Mercaptan Odors	3	WAIT
Mercury Compounds	765	NERC-RTP (Dennis C. Drehmel)
Metal Poisoning	544	WAIT, PTS
Metals, Toxicity	72	
Microbiology Topics (Selected) -Environmental Microbiology -Microbial Contamination -Microbiologic Hazards	120	WAIT, PTS
Municipal Wastes	69	EPA-Wash. DC (Wm. Rosenkrantz)
Nematoda	158	NERC-Cincinnati, OH (J. E. Smith, Jr.)
Noxious Fumes	12	WAIT
Octyl Alcohol	2	WAIT
Odor	448	WAIT
Paint Solvent Air Pollution	12	WAIT
Parathion Water Pollution	1	WAIT
Particulate Air Pollutants	14	PTS
Pasteurization	64	EPA-Wash. DC (Wm. Rosenkrantz)
Pesticides (Selected Topics)	13	NERC-RTP (Robert E. Lee, Jr.)

Fungicides	323	
Herbicides	463	
Insecticides	571	
Molluscacides	33	
Rodenticides	69	
Poisoning	561	WAIT
Pollution Control Phase	30	WAIT
Quality Assurance -Documents -Maintenance -Models -Nondestructive Testing -Standards	52	NERC-RTP (Raymod C. Road)
Quality Control Distribution	77	NERC-RTP (Raymond C. Road)
Quality Control Standards	452	NERC-RTP (Raymod C. Road)
Quality Control Documents	97	NERC-RTP (Raymond C. Road)
Quality Control Organizations	55	NERC-RTP (Raymond C. Road)
Sanitary Engineering	488	EPA-Wash. DC (Wm. Rosenkrantz)
Sanitary Landfills	4	WAIT
Sewage	314	EPA-Wash. DC (Wm. Rosenkrantz)
Sludge	21	EPA-Wash. DC (Wm. Rosenkrantz)
Smoke -Control -Pollution -Stack Emissions	98	PTS
Sulfides -Air Pollution	66	WAIT

-Odors -Water Pollution		
Thermal Pollution	29	
Toxic Air Pollutants	145	PTS, WAIT
Toxic Environments	67	WAIT
Toxic Hazards	35	WAIT
Toxic Hazards Research	22	WAIT
Toxic Materials	114	WAIT
Trichlorethylene Odor	1	WAIT
Uniform-sized Aerosol Particles	670	PTS
Upwelling	101	NAVSURFWPNCEN
Vapor Hazards	142	WAIT, PTS
Virus Particles	18	PTS
Viruses -detection -general	10	EPA-Wash. DC (Wm. Rosenkrantz)
Waste Munitions		NERC-Edison, NJ (R. Tabakin)
Waste Treatment	33	EPA-Wash. DC (Wm. Rosenkrantz)
Water Pollution	1119	WAIT
Water Pollution Problem Areas	1005	WAIT

V. Assessment of Overall Effort

A. Laboratory Quality

It is tempting to attempt comparisons of the laboratories that were visited. However, this was not done due to the very short time spent at any given laboratory. In some cases, depending on the motivation or understanding of the host laboratory, technology that was not particularly relevant was devoted too much time. An attempt is made in this section to make off-hand evaluations of individual laboratories based on limited information. Some general statements and specific mentions can be made of the various particular areas of expertise within the laboratories visited.

The DOD/ERDA laboratories constitute the largest complex of technical personnel in the United States. The laboratories are, as a whole, better equipped with research, development, and test gear than any other system of laboratories in the world. However, collectively over 85% of the effort at these laboratories is directed toward military technology. Much of this technology appears transferable to other government agencies.

Some laboratories such as the Army Land Warfare Laboratory, which closed in 1974, and the Army's Dugway Proving Grounds, which is cutting back significantly, had strong, and in some cases, unique capabilities relevant to pollution technology.

Table V-1 has been prepared as a cursory guide. For a detailed description of laboratory capabilities, refer to Appendix A.

B. Evaluation of Techniques

The techniques used to accomplish Task 1 of IAG 133-D consisted primarily of:

1. determining EPA-NERC-RTP needs and interests in air pollution monitoring,

2. acquainting DOD-ERDA laboratories with the general needs and interests of the NERC

Table V-1

GUIDE TO PROMINENT TECHNOLOGIES AT DOD/ERDA LABORATORIES

Technology	Laboratories With Greatest Expertise*
Health Effects	AFWL, RPL, WPAFB, LLL, SL, LASL, DPG, EA, NDC & VEC, NBRL, NWC
Pesticides	AFWL, LLL, SL, DPG, EA, NDC & VEC, NBRL
Chemistry and Physics	All
Air Quality	AFWL, LLL, DRI. SL, LASL, White Sands, DPG, ACERL, EA, NWC, NRL
Emission Measurements	AFWL, RPL, McClellan, WPAFB, LLL DRI, SL, LASL, DPG, ACERL, EA, NBRL, NWC
Quality Assurance and Monitoring	AFWL, LLL, SL, LASL, ACERL, EA, NWC, NSRDL
Meteorology	AFWL, RPL, LLL, DRI, CRREL DPG, EA, NPGS, NWC, NRL
Instrumentation and Measurement	All
Fine Particulates	AFWL, RPL, LLL, DRI, LASL, White Sands, DPG, ACERL, EA, NWC, NAVSURFWPNCEN, NRL
Other	AFWL, RPL, LLL, DRI, SL, LASL, White Sands, DPG, ACERL, EA, NWC, NRL
Chemical Processes	AFWL, RPL, LLL, SL, LASL, White Sands, DPG, EA, NWC, NRL

*See Section IV C.1. for names of laboratories.

Filters	AFWL, LLL, SL, LASL, DPG, EA, NRL
Sampling	AFWL, McClellan, LLL, DRI, SL, LASL, CRREL, White Sands, DPG, ACERL, EA, NBRL, NWC, NRL, NSRDL
Aerosol Generation	RPL, LLL, DPG, EA, NWC, NRL

3. surveying the laboratories for their developed technology in EPA's areas of interest using both DOD and NERC-RTP representatives

4. transfering the technologies from the laboratories to EPA via written and verbal reports of interview results, documents from the laboratories, hardware, and bibliographies pertinent to EPA interests

5. following-up to insure an open dialogue between the project leader and the laboratories, suggesting points of contact within the NERC and DOD/ERDA laboratory complex (i.e., -- providing an active "linker" role).

This procedure was imminently successful in providing EPA with access to DOD/ERDA technology. Now that the system by which EPA can tap into this technology base has been established, it could and should be exercised by other organizations within EPA.

C. Advantages and Disadvantages

The IAG allowed maximum flexibility in the accomplishment of Task 1 without sacrificing control by NERC-RTP. For example, funds were available for the exploration of specific technologies such as evaluation of the dielectrophoretic filter described in Appendix B.

Few disadvantages in the IAG were noted. As requirements changed when new knowledge or as experience with the project increased, the agreement was modified to accomodate the added alternatives.

The advantages of the IAG became obvious as the task proceeded: NERC-RTP had first-hand exposure through their representative present at most site visits. Also, the technology base of the entire DOD/ERDA laboratory complex was accessible to EPA utilizing WOL as the "pathfinder", so "re-invention of the wheel" could be reduced and taxpayer dollars could be better spent elsewhere. The use of the WOL as a linker with the Consortium also allowed administrative and financial tasks to be centered at one facility, although management perogative still resided at NERC-RTP. This reduced immeasurably the burden on NERC-RTP associated with dealing directly with numerous DOD organizations.

The IAG also most importantly offered the opportunity to focus efforts on closing the informational and technological gaps between DOD and EPA.

1. Problems and Solutions

In addition to the normal problems of project management and the particular anticipated problems attendent with this IAG, the following occurred:

(1) After a few laboratory visits there was far more information available than expected. This result necessitated a modification to the agreement to expand the time frame and scope of the survey task. This situation led to some confusing results. It became unclear whether the main purpose of the agreement was to reduce redundancy, survey DOD technology, gather reports for others, or whatever. At any rate, an "open-ended" approach became the strongest impression for the investigators on how the effort should proceed.

(2) A major difficulty arose in March of 1975 when it was discovered that the completion of Task 2 would require approximately twice as much funding as initially requested by NAVSURFWPNCEN (DL). This, in effect, stopped all progress on Task 1 and the remaining laboratories could not be visited. Also work planned for FY 76 including on-going R&D in DOD laboratories which would result in contributions to near-term pollution monitoring and control technology could not be initiated.

VI. Appendices

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Appendix A

Detailed Laboratory Capabilities in Air Pollution

Non-DOD Laboratories

One non-DOD laboratory (Desert Research Institute, University of Nevada at Reno) was visited in addition to DOD related Atomic Energy Commission (AEC) laboratories (now ERDA). Scheduled for visits were the National Laboratories at Brookhaven, New York; Argonne, Illinois; and Oak Ridge, Tennessee. However, funding did not permit these visits.

Among the AEC laboratories, the Oak Ridge Laboratory has achieved a high degree of diversification, while Argonne National Laboratory (ANL) has focused primarily on the environmental sciences and captured a larger share of the EPA market than any other AEC facility. Laboratories having special missions, (weapons research, etc) have tended to respond least to the opportunity to diversify, although a significant pollution technology capability exists in some of the laboratories; e.g., Sandia Laboratories. The inadequacy of the scientific and technological resources that are currently available to most state and local agencies (not to mention the federal EPA regional administrative offices) underscores the need for centers of excellence comparable to those that have supported the national atomic energy and aerospace programs. Neither the academic community nor the commercial research and development sector has satisfied entirely this need. Academe has generally been unable to mount mission-oriented, schedule-sensitive programs, while profit oriented groups have all too frequently proven unable to produce usable results through failure to communicate effectively and inadequate follow-up.

Argonne National Laboratory (ANL), Argonne, Illinois - Although ANL was not visited, telephone contacts and documents originating from ANL have provided an overview of their capabilities. The Center for Environmental Studies provides a focal point for the coordination of environmental science programs throughout the Laboratory, and an interdisciplinary core group within the Center proposes and conducts environmental systems analysis studies. The activities of the Center include development of environmental data management systems, computerized simulation models of physical and socioeconomic processes, development of techniques for planning and evaluation of environmental protection regulations, policies and programs, and studies of the environmental impact of land use, urban development, transportation systems, and energy systems.

Large-scale programs to develop and evaluate advanced techniques for the control of pollutant discharges are conducted by the Argonne Chemical Engineering Division, while the Radiological and Environmental Research Division performs terrestrial and fresh water ecological studies and atmospheric science research. The Division of Biological and Medical Research studies the toxicology of environmental contaminants, pollution-related genetic damage to man and the biota, and investigates chemical, molecular, and transport processes in biological systems. The Chemistry Division and the Electronics Division develop and apply advanced techniques for monitoring ambient pollution concentrations and for analysis of samples. Several of Argonne's projects are familiar to EPA already, such as the reduction of atmospheric pollution by the application of fluidized-bed combustion and episode control strategy development.

Additionally, ANL has participated in state and local government projects including: Air pollution and land use planning of airports and the collection of major point- and area-source emission inventories; the construction of a data management system (APICS) for storing and retrieving emission, meteorological, and air quality data; the development of computerized steady-state and transient atmospheric dispersion models for simulating ambient air pollution distribution in urban areas of Chicago and the development and field testing of techniques for episode control planning, energy management during episodes, and the integration of air pollution control into long-range planning.

Under the sponsorship of the Illinois Institute for Environmental Quality and the Illinois Environmental Protection Agency, ANL prepared the state implementation plan for the control of sulfur oxides, suspended particulates, carbon monoxide, nitrogen oxides, hydrocarbons, and photochemical oxidants.

Desert Research Institute (DRI), Reno, Nevada - As part of the University of Nevada, DRI has responsibility for a broad range of pollution research, including:

1. Pollution monitoring of the large coal-burning powerplant at Mojave, California (atmospheric and ground level).

2. Plume monitoring from aircraft (.3 - .20μ).

3. Transmissometer data gathering.

4. Analysis - proton bombardment, nanogram samples (can identify all elements above sodium in the periodic table).

5. NO_x and SO_x concentration analysis.

6. Unique sample designs and fabrication.

7. Fog studies, including ice crystal formation and weather modification.

8. LIDAR measurements of ice crystal layers in clear air over the poles.

9. Ability to relate SO_x in a plume to the amount of sulfur in coal.

10. Water pollution.

The DRI tunable organic dye laser is capable of remotely detecting particles in the atmosphere to ranges beyond 10 km. Their solid state laser has a range of 1.5 km.

Details of each year's programs are found in DRI's Annual Report.

Points of Contact: Roger Steel (Laboratory of Atmospheric Physics).
Joe Warburton (Weather Modification)
Richard Egami (Solar Energy)
Dr. Vern Smiley (LIDAR)
(Tel: (702) 972-1676)

Sandia Laboratories, Albuquerque, New Mexico - Although mainly involved in DOD research and energy related projects, Sandia possesses possibly the finest instrumentation capability in the world for air pollution monitoring and control technology. Included in their overall capability are:

1. Materials Analysis. Every known technique for analyzing elements and compounds is in use at Sandia. In addition to "standard" techniques, such as, x-ray fluorescence, neutron activation analysis, and scanning electron microscopes, Sandia possesses unique analytical tools, such as, automatic microprobes for $Z>5$ materials that characterize surface composition of a sample, and dye lasers for characterizing where each atom is located in a crystal. Their dye lasers are capable of identifying inpurities in a material in the 10 parts per trillion range.

2. High level nuclear waste disposal. This precipitation technique requires only 1/20 the storage requirements and produces a homogeneous dispersion.

3. Atomization of fluids by shockwave techniques.

4. Particulate flow chamber. This chamber can produce .05 to 1μ sized particles and accelerate them from 1 to 50 mph. Used for resuspension studies, the chamber is instrumented with a laser doppler velocimeter similar to Dr. Yanta's at NAVSURFWPNCEN, (WOL) except the Sandia device is low velocity and can handle large mass flow.

5. Airborne pollution studies. Project "Di Vinci" was a manned balloon saturated with a myriad of experiments. Sandia technology miniaturized many standard sensors for this project.

6. Chemical Vapor Deposition. A cheap particulate generator good for 1/2 μ and larger (perhaps even smaller). Good to better than 30 cu ft/min flow rates.

7. Breakthroughs. Among others, Sandia has discovered and is exploiting the synergistic effects of diathermy and radiation on desoryribonucleic acid (DNA). The technique destroys virus and bacteria 30 times faster than the sequential application of radiation and heat. The method should be good for sterilization of blood, tools, liquid and solid wastes, and useful in cancer therapy and vaccine agent attenuation.

8. Systems Analysis. A computer model of the entire eco-chain with subroutines for man (his internal organs), plants, animals, and crops has been developed. For example, the model will provide an output for what happens to a human liver if you increase the amount of nickel in the air by an arbitrary amount.

An example of their capability to model the deposition/ resuspension phenomena follows:

Although the data are incomplete, one can conclude that the deposition/resuspension process is governed by the physical properties of the particles and the properties of the turbulent flow. Hence, any experiments which are intended to model the deposition/resuspension process must be conducted in a controlled, repeatable environment where both the flow field and the particle characteristics are known. These conditions are difficult to accomplish in the atmosphere because the flow field is so complex and the winds are not steady in either speed or direction. As an alternative, simplified experiments can be conducted in a wind tunnel rather than in the atmosphere.

Sandia Laboratories' Atmospheric Wind Tunnel is a facility which was constructed specifically to provide a controlled environment for the study of atmospheric flows. Particle deposition and resuspension rates can be measured in the zero-pressure-gradient turbulent boundary layer growing on the test section floor. The test section is 9 inches high, 16 inches wide, and 12 feet long; the exceptional length of the test section produces thick turbulent boundary layers without resorting to artificial thickening devices which may disturb the equilibrium nature of the boundary layer. The test section velocity can be varied between 0 and 50 mph. The tunnel is designed so that the test section walls, ceiling, and floor can be replaced by special sections for mounting flow-field instrumentation, injecting particulate material into the flow, or changing the roughness of the floor surface. The simplicity of the tunnel construction makes it possible for such modifications to be made at low cost and with minimal effort. The Atmospheric Wind Tunnel is fully operational and has been used successfully in experimental studies of rough-wall boundary layers.

The versatile features of the Atmospheric Wind Tunnel can be utilized in parameter studies to identify the principle flow and particle characteristics affecting deposition and resuspension rates. Experiments can be conducted for various surface roughness heights, roughness shapes, and free-stream velocities. In each case, the boundary layer flow can be thoroughly surveyed at several test section stations to define the environment in which particle deposition and resuspension takes place. Particle size and concentration can be varied for each test condition and roughness configuration; deposition and resuspension rates would be determined by recording the velocities of the particles at various distances from the test section floor in the boundary layer.

Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico - The Industrial Hygiene, Health Physics, and Environmental Studies groups of LASL are involved in pollution monitoring and control projects. Within their Industrial Hygiene group are programs for the analysis and characterization of fine particulates, and a variety of applied studies requiring development of highly specialized aerosol techniques and instrumentation. Considerable attention is directed toward the preparation of unique laboratory, fibrous, coal dust, and plutonium test aerosols, to simulate particulate dispersions of major concern in the area of occupational and environmental health. Specialized analytical procedures involving electron and light microscopy, aerodynamic and light scatter size characterization, and nuclear track counting have been developed.

Specific program areas include:

1. development of quality control standards and procedures for use by the National Institute for Occupational Safety and Health (NIOSH) to evaluate worker exposures to asbestos;

2. Definition of plutonium aerosol source terms and design of air cleaners for plutonium facilities;

3. Evaluation of aerosol aerodynamic properties and its relation to fibrous filters used for air cleaning and sampling;

4. Development of aerosol systems for the National Institute of Occupational Safety and Health (NIOSH) testing and certification of respirators and air samplers;

5. Evaluation of multi-stage air sampling instruments and procedures to better estimate inhalation hazard to the individual;

6. Development of air sampling systems to distinguish between particulate and non-particulate mercury;

7. Development of the LASL Spiral Centrifuge Aerosol Spectrometer to define aerosol aerodynamic properties;

8. Study of particulate agglomeration and its relation to the performance of air cleaners.

Primary attention has been directed at the development of monodisperse test aerosols ranging from 0.2 to 10 μm, employing nebulization and spinning disc techniques. Test methods have been developed for generating fibrous and coal dust aerosols with specific polydisperse size characteristics. Electron and light microscopy, and aerodynamic size characterization have been used to define particle size parameters. Variation in aerodynamic size for non-hygroscopic aerosols has been studied as a function of high humidity conditions similar to that existing in the lung. Field studies have been directed at defining size characteristics of plutonium aerosols under actual work conditions in order to provide an estimate of the source term for air cleaning systems. Aerodynamic shape factors and particle density have been defined for non-spherical aerosols using the LASL Spiral Centrifuge Aerosol Spectrometer.

Two-stage samplers have been calibrated in relation to "respirable" dust sampling concepts, and theoretical relationships between different "respirable" dust standards have been developed. Studies to develop a "respirable" sampler for fibers are currently in progress. Laboratory studies have been directed at defining filter efficiency as a function of aerosol size, filtration velocity, mass loading, cyclic flow, and media characteristics. Cyclic flow conditions simulate different breathing patterns, and approximate actual respirator use conditions. Experimental filter performance data have been related to theoretical calculations. An experimental program is in progress to define the performance of multiple high efficiency filtration systems. Test methods have been developed for in-place testing of high efficiency filtration and sorbant air cleaners, which required development of a new light scatter photometer for monitoring small aerosol concentrations. Agglomeration of test aerosols used for in-place filter testing is being studied in terms of changes in particle size, and the effect on filter performance. A computer program has been developed to model air cleaner performance in terms of mass removal, reduction in potential health hazard, and haze formation, and as a function of challenge aerosol size characteristics.

The central point of contact for these technologies is Mr. Harry Ettinger, (505) 667-5231.

Lawrence Berkeley Laboratory, (LBL) Berkeley, California

Two visits were made to LBL, the second was made to follow-up on items uncovered during the first visit. LBL is actively involved in several energy and pollution projects, including the exploitation of geothermal energy, clean coal, solar energy, nuclear fusion, water purification, air quality research, instrumentation for environmental monitoring, and earthquake prediction.

The strongest air pollution technology LBL seems to have is in the area of trace-substance detection and analysis. The technique is good for heavy metal oxides but best for characterizing NO_x, SO_x, etc. A single scan on a 100 nanogram sample will yield sufficient information to determine which heavy metal oxides and pollutants such as NO_2 and SO_3 are present. Also, the technique can identify particles smaller than 100Å. This has importance because, e.g., ultrafine carbon particles apparently catalyze $SO_2 \rightarrow SO_4$. Leasing cost for a new analytical machine is about $25K/year, plus $35K/year for personnel. A "leisurely" sample analysis rate yields a gross total cost of about $60/sample.

Other areas of expertise and hardware available at LBL include:

1. X-ray fluorescence.
2. Photoelectron spectroscopy (ESCA).
3. Isotope-zeeman absorption spectroscopy.
4. Resonance-Raman lidar spectroscopy.
5. Laser optoacoustic spectroscopy.
6. Microwave spectroscopy.
7. Mass spectroscopy.
8. Survey of instrumentation for environmental-quality monitoring.

LBL is engaged in the development and improvement of two techniques for the measurement of the elements present in pollutants, such as mercury, cadmium, and zinc. X-ray fluorescence is the more versatile and is capable of measuring practically all the elements, but, for those elements for which it is suitable, Isotope Zeeman Effect Atomic Absorption (IZAA) has higher sensitivity.

The recent development of LBL semiconductor-detector spectrometers with energy resolution adequate to discriminate between most elements has yielded an almost ideal tool for rapid simultaneous multielement analysis. The sensitivity of x-ray fluorescence analyzers has been improved so that trace-elements in air pollution samples or biological samples at less than 1 part per million can be measured in a few minutes per sample. This work has recently been applied, together with automatic computer analysis of x-ray spectra, to an air particulate analysis system developed by LBL for EPA is now in use. Thus, it will not be discussed further here.

The laboratory is developing, extending, and putting to use the IZAA method for trace-element analysis. Recent work has proven that atomic absorption analysis can be performed on mercury in the presence of large amounts of attenuating smoke or other elements. Consequently, analysis can be performed by atomizing the sample without chemical separations or pre-concentrations, as required with other trace-element analyzing instruments.

An NSF/RANN is supported effort incorporating new engineering developments into the IZAA instrument to convert it from a proof-of-concept research tool to a practical field-service applied technology instrument. A rugged table-top instrument and a small power supply package are being developed. The result should be a practical device more sensitive, rapid, and easy to use than any other for trace analysis of mercury, cadmium, and lead.

The chemical state of the elements present in pollutants determines their route through the environment and their impact on living organisms. However, x-ray fluorescence and IZAA are not capable of determining the chemical states of elements they detect. This capability is the particular value of the technique knows as Electron Spectroscopy for Chemical Analysis (ESCA). Photoelectron spectroscopy has been developed at LBL into a tool by which many problems of interest in environmental chemistry can be studied. For example, seven different chemical species of sulfur were identified by LBL in aerosols from Los Angeles and San Francisco.

ESCA is presently employed to identify anions such as sulfates, sulfides, nitrates, etc. The oxidation states of detectable metals also are identifiable through chemical shift measurements. The Laboratory intends to broaden their analytical capability of electron spectroscopy by measuring phenomena which could "fingerprint" the anions attached to a particular metal atom. However, operation of the device is somewhat complicated and requires a highly trained person to made it work.

The Resonance Raman Effect (RRE) is being investigated at LBL as a possible method for the long-range, remote sensing of molecular pollutants in the atmosphere. The Raman scattering efficiencies may be enhanced greatly by use of laser light close to a frequency at which a molecule absorbs light. LBL is investigating the use of RRE to detect pollutant gases using a tunable laser (variable light frequency). Calculations indicate possible detection of pollutant concentrations of 1 part per million at a distance of a mile or more. Then, by measuring the round trip time of light pulses, three-dimensional map of pollutant distributions in the air maybe constructed to identify pollutant sources and to study movement of pollutants in the atmosphere.

LBL is also investigating the use of Microwave Spectroscopy as a highly specific and sensitive method for monitoring gaseous molecular pollutants and studying chemical kinetics of pollutants. The sensitivity of the spectrometer system can be made adequate for direct measurement of gaseous molecular pollutants in ambient air at the parts-per-billion level with a measurement time of one second or less. The design goal is a portable spectrometer for field measurements of SO_2, CO, and H_2S with high sensitivity and instant read-out.

In 1972 LBL began a critical and in-depth Survey of Instrumentation for Environmental Monitoring under the auspices of NSF. Instruments and techniques being investigated are those useful for measurements in air, water, radiation, and for environment-related biomedical monitoring. In addition to filling an information gap, such a survey has highlighted new methods of detection and analysis, and techniques employed in other disciplines which appear to be applicable in the environmental field.

The survey included summaries of conditions giving rise to environmental problems, overviews of present measurement methods, critical comparisons among instruments and instrumentation methods, and recommendations for the development of new instrumentation.

LBL is carrying on a program of Air Quality Research to study air pollutants emitted from combustion sources. This program addresses the questions of how the pollutants are formed, how they are transported through the environment, how they interact with non-living and biological systems, and how they affect the human health.

A major LBL environmental program involves the chemistry of atmospheric particulate matter, with the long-range goal of gaining an understanding of the formation and chemical nature of atmospheric aerosols. One ubiquitous pollutant is sulfur dioxide. A primary goal of the LBL study is to understand the chemical transformations of the sulfur in fuel, all the way from combustion to the formation of the final sulfurcontaining compounds in the atmosphere. This work using ESCA has been carried out in collaboration with the

California State Air Resources Board. A major result thus far has been the identification of the important, and heretofore not realized, role played by finely divided carbon particles (soot) in the chemical transformations of sulfur from the fuel into sulphate ion, and subsequently into sulphuric acid.

LBL has re-analyzed the classic study of the health effects of air pollution conducted in 1962 by Winkelstein and others in Buffalo, New York using the advanced instrumentation described above, the more than 2500 air samples collected in the original Buffalo study and, for the first time, measured the concentrations of individual elements in the samples. LBL has proposed to re-establish the 21 sampling stations in Buffalo with special equipment designed for the collection of suspended particulates for analysis by advanced instrumentation techniques. These measurements would be combined with a study of the morbidity and mortality distributions in Buffalo to be performed by Winkelstein of the University of California School of Public Health. The goal is the determination of the occurrence of cancer vs. specific chemical composition of ambient aerosols.

The significance of trace-element pollution of ambient air to human health and disease rests, of course, on the assumption that body burdens are related to ambient air levels. LBL hopes to test this hypothesis by examining selected tissue samples for presence and amounts of studied elements, utilizing the x-ray fluorescence technique as well as other appropriate chemical and physical methods. Such materials as hair, capillary blood, saliva, and possibly urine are easily available from school children; this population provides a geographically representative sample. The tissue levels can then be compared to ambient air levels at place of residence to test the hypothesis of association.

While epidemiological studies, such as the Buffalo study, demonstrate a correlation between health effects and air pollution, such studies tell us nothing about the underlying mechanisms by which the pollutants affect living organisms. LBL has undertaken laboratory studies directed toward elucidation of these mechanisms. One possible mechanism by which pollutants could affect living systems is by interacting with the structure and function of cellular membranes. For example, there is evidence that the growth of cells is limited by environmental influences that can cause damage to the cell membrane. Because membranes are the critical interfaces that screen the complex organization of cells from their environments, they are utilizing human lung-cells to develop sensitive and specific methods to detect and evaluate the effects of pollutants.

Another possible mechanism by which pollutants might affect health is by alteration of biological enzyme systems. The state of health of humans depends upon the optimal functioning of a multitude of enzymes which control almost all body processes. Many of these, perhaps a majority, either contain an essential metal as an integral part of their structure or are activated by a particular metal. LBL researchers are investigating what happens to these metal-dependent enzyme systems when humans are exposed to abnormal amounts or kinds of metal as particulate matter in our air, from accumulation of industrial wastes in our water, or in our food supply. Especially important are synergistic effects, about which essentially nothing is know. They wish to develop methods for early detection of disturbed enzyme systems, before signs of tissue pathology appear. The experimental focus will be on changes in metal content within the cells as a forerunner and clue to changes in enzyme activity.

Points of contact include: Dr. Jack Hollander, (415)843-5878 and Dr. T. Novakov, (415)843-5110 (ESCA).

Lawrence Livermore Laboratory (LLL), Livermore, California

Although deeply involved in energy research, LLL additionally has air pollution monitoring and control capabilities (primarily in the area of fine particulates). The Biomedical Division conducts efforts associated with instrumentation, meterology, aerosol generation and measurement, pollution chemistry, and analysis suspension and resuspension, particle collection and generation, aircraft sampling, and power plant effluents.

More specifically, LLL has current work ongoing in areas of:

1. Global climate modeling.
2. San Francisco Bay air pollution modeling.
3. Aerosol characterization.
4. Ammonia vapor detection.
5. Asbestos quantity measurements.
6. Automatic chemistry lab at NERC, Cincinnati.
7. Ecosystems.
8. Methylation of Platinum.
9. Gamma-ray cameras.
10. X-ray flourescence (elemental analysis).
11. Gunn diode spectrometer (gas analysis).

The Chemistry and Material Science Division is concerned (from an environment point of view) with aerosols, emissions from smelting plants fine particulate generation, ESP's and automation. Fine particulates are emphasized, with a capability for 100 Å resolution in concentrations down to the ppB region.

The Analytical Chemistry Division has a device that can characterize SO_2 vs SO_3 compounds as well as any other compound. Molecular configurations are identified by peering into the first five layers of atoms on surfaces. For example, the device can characterize and identify vinyl chloride in concentrations as low as 10 ppB.

LLL also has instrumentation available that can characterize particulates in a range from 50 Å diameter to "boulders." Aerosol generation (mono- and poly-dispersed), stack sampling equipment, and upper air sampling are also within LLL capability.

In addition to a rather broad and deep hardware and analytical capability, LLL possesses the ability to put teams of scientists and engineers together to apply the cybernetic approach to solving complex problems. This is largely a function of the matrix organization of LLL.

Table VI-1 shows the detailed type of pollution work LLL has been involved in recently. Additionally, LLL feels confident they can solve the following types of problems.

1. Model the deposition of aerosol particles in the human respiratory tract during breathing.

2. Model the particulate distribution effects on passing through an electrostatic precipitator, fabric filter or other collection device.

3. Promote research and development on electrostatic techniques and Brownian diffusion techniques for developing automated instruments for stacks.

4. Develop an optical particle counter which can operate directly within the effluent stream.

5. Apply holographic techniques for sizing applications in effluent streams; decrease equipment costs and complexity; increase resolution.

6. Investigate and test techniques which use the size limitations of several different concentration sensors to effectively measure particle concentration within several size ranges. The technique would use (1) a beta radiation attenuation sensor to measure the total particulate mass concentration (sensitive to D_p^3, or large particles in the 1 - 100 μm range), (2) a transmissometer to measure opacity (roughly sensitive to D_p^2, or particles primarily from 0.1 - 10 μm) and (3) a condensation nuclei counter or electrostatic counter to measure the particle number concentration (sensitive to the number of particles, or to particles from 0.001 - 1.0 μm). Analysis of the three simultaneous measurements would appear to offer sufficient particle size information for most continuous air pollution monitoring applications. Measurement of total mass concentration and respirable mass concentration offers another interesting combination of particulate parameters.

7. Develop techniques for delivering truly representative samples of effluent to measuring instruments. Questions related to

the conditioning of the effluent (dilution, heating, cooling, etc.) prior to measurement by most sizing instruments could also be investigated thoroughly.

8. Source sampling with more advanced instrumentation (e.g., cascade impactors, thermal precipitators, and electrostatic precipitators) to define the effectiveness of control equipment for the collection of particulate pollutants.

9. Study methods for the collection of research directed to these main areas: (1) improvement of existing control equipment via better design, (2) development of devices for controlling fine particles, and (3) agglomeration mechanisms of fine particles. Research on the agglomeration mechanisms could improve existing collector performance and may lead to new collector devices.

10. Improve the capability to monitor, sample, and size effluents from particulate pollution sources. Optical techniques for monitoring fine particle emissions could be pursued. Simple, yet reliable stack sampling methods can be developed. A collection mechanism which collects submicron particles and causes neither a formation nor a break-up of aggregates is necessary if accurate particles size formation is to be obtained.

11. Research the relationships between total suspended particulate in the air and specific sources of particulate pollution emphasizing submicron size particulates. Information is needed to help identify the origins of suspended particles in the air and to assess the contribution of various sources to the total particulate burden in the atmosphere. Investigations could focus on material that leaves the source as a particulate (i.e., primary particulate), and source effluents that form particulates after leaving the source (i.e., secondary particulates). Reduction of total suspended particulate matter may require control of the source of effluents that form secondary particulates.

12. Conduct epidemiological and laboratory studies of the effects of particulate pollutants on humans, including experiments on animals. Attention focused on synergistic effects produced by gases in combination with particulates.

13. Gather information on chemical composition of particulate pollutants as a function of particle size should be obtained to assist in defining potential health hazards of particulate pollutants. Attention could be focused on potentially harmful metals.

14. Assess the material damage caused by fine particulate pollutants.

15. Investigate the influence of suspended-particulate matter on the behavior of the atmosphere should be defined in more detail.

tention can be focused on their effect on solar radiation and ather modification.

16. Study emission standards since the major adverse effects f particulate pollutants on human health and welfare are associated ith micron and submicron particles, the technical and economic easibility of establishing national emission standards based on article size could be investigated. Performance or emission tandards based on particle size should be studied because there is reat doubt that procedures which are based on overall percentage eduction in emissions (tons/year) actually achieve the desired eduction in suspended particulate matter in the community air.

17. Develop simple, accurate, and reliable methods for testing the performance of various control devices in the fine-particle (0.1 - 1.0 μ diameter) range. These test procedures will be needed to confirm compliance of installed equipment with regulations as well as to provide a means of comparing performance capabilities of various devices on a single source.

18. Study the long-term health effects of particulates in the human lung - dissolution and expulsion; residence times and sticking coefficients as a function of particle size and composition.

19. Study the nucleation and condensation mechanisms of particulates as a function of stack gas temperature downstream from the cleaning device.

20. Study synergistic health effects by monitoring < 2 micron particulates in three cases: (a) 100% particulate removal with no SO_2 control, (b) 100% SO_2 removal with no particulate control, and (c) 50% particulate control - 50% SO_2 control.

21. Study the effect of leaving > 2 micron particles in the gas stream to act as gaseous absorbers and remove only less than 2 micron particles.

22. Study aerodynamic behavior of particulates in the human lung using actual physical particle linear dimensions rather than aerodynamic diameter.

23. Model real systems by characterizing linear dimensions and chemical compositions of particulates.

24. Provide R&D to (a) develop gas cleaning equipment whose performance is based on particle size as well as on weight removal, and (b) improve the collection efficiency of electrical precipitation, filters and scrubbers in the critical 0.1 - 1.0 μ range.

25. Develop a better understanding of the origins and effects of particulate pollution in relation to public health needs and the economic impact on industry of current standards.

Attention can be focused on their effect on solar radiation and weather modification.

16. Study emission standards since the major adverse effects of particulate pollutants on human health and welfare are associated with micron and submicron particles, the technical and economic feasibility of establishing national emission standards based on particle size could be investigated. Performance or emission standards based on particle size should be studied because there is great doubt that procedures which are based on overall percentage reduction in emissions (tons/year) actually achieve the desired reduction in suspended particulate matter in the community air.

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20. Study synergistic health effects by monitoring < 2 micron particulates in three cases: (a) 100% particulate removal with no SO_2 control, (b) 100% SO_2 removal with no particulate control, and (c) 50% particulate control - 50% SO_2 control.

21. Study the effect of leaving > 2 micron particles in the gas stream to act as gaseous absorbers and remove only less than 2 micron particles.

22. Study aerodynamic behavior of particulates in the human lung using actual physical particle linear dimensions rather than aerodynamic diameter.

23. Model real systems by characterizing linear dimensions and chemical compositions of particulates.

24. Provide R&D to (a) develop gas cleaning equipment whose performance is based on particle size as well as on weight removal, and (b) improve the collection efficiency of electrical precipitation, filters and scrubbers in the critical 0.1 - 1.0 μ range.

25. Develop a better understanding of the origins and effects of particulate pollution in relation to public health needs and the economic impact on industry of current standards.

26. Develop and extend chemical element balances and other methods for estimating natural background levels.

27. Relate standards for the chemical components of particulates including sulfates, lead and other constituents to physical characteristics.

28. Improve existing in-stack sampling systems and develop new stack monitoring systems capable of measuring the physical and chemical characteristics of particulate emissions.

29. Develop methods which relate air quality to emission sources, both gaseous and particulate, for urban and industrial regions with differing source characteristics.

Table VI-1

LLL ENVIRONMENTAL STUDIES CURRENT PROJECTS

Title and Description	Funding Agency
DOT CIAP MODEL DEVELOPMENT Develop numerical models of atmospheric processes as an aid to understanding the impact on global climate caused by aircraft exhausts in the stratosphere.	Dept. of Transportation
NSF BAY AREA AIR POLLUTION MODEL DEVELOPMENT Jointly with NASA-Ames Research Center and the Bay Area Air Pollution Control District develop and verify a numerical model for conventional and photochemical air pollution in the San Francisco Bay Area. The model will include meteorological and topographical data and will be a useful tool in evaluating land use plans, studying consistency of local air quality standards, and assessing the effect of various postulated emission control strategies.	NSF-RANN
CALIFORNIA DEPARTMENT OF HEALTH - AEROSOL CHARACTERIZATION Measure, using neutron activation analysis, the abundance of selected trace elements from particulate matter collected on filters and impactor foils by personnel of the Air and Industrial Hygiene Laboratory of the State of California Department of Public Health. Analyze and interpret the results using existing laboratory computer programs and report the results to AIHL.	State of CA - Air Resources Board
DEVELOPMENT OF MICROWAVE CAVITY SPECTROMETER FOR AMMONIA VAPOR DETECTION To develop an instrument for observing the presence and variation in concentration of low quantitative levels of ammonia gas by monitoring a selected absorption line of its microwave inversion spectrum. An open type microwave resonator cavity will be used as the frequency	State of CA - Air Resources Board

selecting structure for a small microwave generating diode while simultaneously acting as the absorption cell of the spectrometer.

FEASIBILITY OF USING THERMOLUMINESCENCE OF ASBESTOS AS A MEASUREMENT TECHNIQUE Develop a method and prototype instrument which can be used to rapidly and reliably measure time integrated dust concentrations in air. The technique to be investigated uses the thermoluminescence of irradiated asbestos on an air filter to give an accurate measure of the quantity of asbestos collected on the filter.	EPA
EPA PILOT LABORATORY COMPUTER SYSTEM Develop a detailed systems analysis for implementation of a proposed centralized computer operated Chemistry Lab at EPA's Cincinnati NERC.	EPA
METHYLATION OF PLATINUM Study the chemical kinetics and conditions for methylating platinum by MeB_{12}. Study the effects of methylated platinum compounds on cell growth.	EPA
CARB X-RAY FLUORESCENCE Design, construct, and experimentally evaluate an x-ray fluorescence system for rapidly determining the elemental composition of samples of airborne particulate matter.	CA - Air Resources Board
EPA/NASA SPECTROMETER DEVELOPMENT Develop an instrument to observe the presence and variation in concentration of low quantitative levels of Formaldehyde gas by monitoring a selected absorption line of the microwave rotational spectrum. An open type microwave resonator cavity will be used as the frequency selecting structure for a microwave generating "Gunn diode" while simultaneously acting as the absorption cell of the spectrometer.	EPA/NASA

Air Force Laboratories

The Air Force uses 57% of all DOD petroleum (DOD uses 3½% of the total U.S. requirement).

Air Force laboratories, in general, seem to have more direct contact with EPA than the other services, therefore, not as much in the way of laboratory capabilities will be mentioned in this section compared with the Army and Navy sections.

Laboratories Not Visited

Tyndall Air Force Base, Florida (just beginning to get into pollution projects).

Air Force Cambridge Research Lab - Primarily concerned with stratosphere and outer space physics, but they claim a good capability in meterology (including fog, aerosols, etc.).

Brooks Air Force Base - responsible in the Air Force for personnel health (toxicology) and safety.

Laboratories Visited

Rome Air Development Center (RADC, Rome, New York) - Rome, located on Griffiss Air Force Base, has developed a technique of remotely monitoring gaseous and acidic pollutants down to 4 ppB (cut to about 6 Km). Infrared laser techniques using Raman spectroscopy are used in the field, not just in the laboratory. Also, a technique for quantitatively monitoring condensable gases has been developed at Rome for the purpose of characterizing integrated circuit atmospheres. However, it is possible to apply this technique to quantitative air pollution measurements.

The point of contact at RADC is William Kelley, (315)330-3046.

Rocket Propulsion Laboratory (RPL), Edwards Air Force Base, California - RPL already has an established liaison with EPA, and reports are exchanged. The following then, reitterates work at RPL applicable to pollution monitoring and control.

Beryllium diffusion characterization health hazards NO_x studies,

Large scrubbers,

Disposal and neutralization of liquid, and solid wastes,

Toxic substances impact on the environment (HCl, Al_2O_3, etc.)

Flame analysis,

Micrometerology (computerized diffusion of particulates),

Points of contact at RPL include:

Lieutenant Colonel Gerald Stewart, (714)553-2206, and Jack Hewes and John Nakamura.

McClellan Air Force Base, Sacramento, California - McClellan is responsible, within the Air Force, for monitoring all Air Force facilities in pollution and recommending corrective action. They build their own and modify existing equipment to suit the specialized work they do.

Primarily, McClellan does all Air Force stack sampling and issues reports (some of which are cited in the bibliography in this report) on their findings, along with recommendations -- however, they cannot enforce compliance.

Point of contact: Major P. Gokelman, (415)964-3821.

Wright-Patterson Air Force Base (WPAFB), Dayton, Ohio - Although primarily involved in noise pollution abatement, WPAFB is also conducting programs concerned with health hazards caused by air pollution. However, most everything WPAFB has done applicable to air pollution is available or has been imparted to EPA; therefore, it will not be mentioned here.

Points of contact: Ken Hopkins, (513)785-5421 and Captain Blazowski, (513)785-2460. (Steve O'Near at NERC-RTP has most of the WPAFB publications concerning pollution).

Air Force Weapons Laboratory

The Air Force Weapons Laboratory (AFWL) is responsible to the entire Air Force for pollution monitoring and control efforts - they are currently the "single point-of-contact" within the Air Force for technology and fund most all Air Force effort in pollution monitor and control, although this function may move to Tyndall Air Force Base (Florida) in the future.

Two visits were made to the AFWL Environics Branch. Within this branch are air, solid, and water sections and the ecosystems technology section. Major emphasis is on pollution control engineering and disposal technology.

The Air Resources Section is investigating procedures to contol or eliminate identified sources of air pollution in the Air Force. Efforts for establishing standards for evaluating pollution sources and for developing technology to control the pollution are being coordinated with the USAF Environmental Health Laboratories.

Representative projects at/funded by AFWL include:

1. Air Force pollution emission factors.
2. Smoke abatement system for crash/rescue training fires.
3. Combustion-incineration products of plastics and films.
4. Smoke abatement methods for jet engine test cells.
5. Film destruction/silver recovery.
6. Standards and criteria studies.
7. Control and disposal techniques.
8. Instrumentation development.
9. Remote monitoring.

One of the efforts at AFWL concerns the Air Quality Assessment Model (AQAM). This model, supposedly an amalgam of the best parts of the EPA, AQDM, and Dugway geometric model plus new concepts, ranks with the EPA, Argonne, and Army Natick Lab models for airports. The AQAM output provides contour plots of pollution. An

IAG exists between AFWL and National Environmental Research Center (NERC) - Las Vegas concerning AQAM application.

AFWL also has an operational mobile air pollution monitoring van.

Major Pete Crowley is the point of contact, (505) 247-1711, X2050. Also, Colonel Frank Smith at Andrews Air Force Base, Washington, D. C, (202) 981-2584 is familiar with all Air Force air pollution work. He can also provide information on all on-going Air Force work in air pollution through a computerized system called MASIS.

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Navy Laboratories

Naval Electronics Laboratory Center (NELC), San Diego, California

NELC has not been involved in significant work relating to air, water, or solid waste pollution control. However, NELC possesses a strong electronic instrumentation capability which is considered as able to provide technology for pollution control.

A special frequency modulated continuous wave radar, operational at NELC, that can detect the sex of houseflies at a range of 10,000 feet was discovered. The radar has characterized the refractive structure of the lower troposphere and might be useful for certain air pollution research problems as CAT, the fine scale structure of rain, and atmospheric motion.

Naval Disease Control and Vector Ecology Center Oakland, California

Current capabilities:

1. Design and evaluation of ultra-low volume aerosol generating equipment (one ounce per minute).

2. Effects of climate on pesticide control.

3. Insectory - breeding, growing, etc.

Point of contact:

Lieutenant Commander Mulrennan (415) 869-3652

Reference:

The Military Entomology Service at Walter Reed Medical Center in Washington, D. C. can provide computer printouts of all known pesticides, their toxicity, etc., (202) 576-5366.

Naval Undersea Center (NUC)

NUC is primarily concerned (pollution-wise) with water pollution problems. During the visit the IAG had not been expanded to include the impact on air of water pollution. A follow-up visit was not possbile to determine the extent of NUC technology involving the air-water interface. Capabilities for water pollution research include ocean biology, chemistry, and modeling.

Naval Biological Research Lab (NBRL), Alemeda, California

Current projects and capabilities:

1. Microaerofluorometer can track plumes out to 150 miles against a background of 10,000 other particles.

2. Aerosol sampling tubes.

3. Programmable environmental chambers that can simulate even the atmosphere of Jupiter.

4. Studies of bacterial growth in the atmosphere.

5. Aerosol particle size vs. toxicity studies.

6. Solar chambers for determining the affect of sunlight on organisms.

7. HEPA filtered 10,000 cubic feet per minute wind tunnel.

8. Identification of airborne proteins.

9. Effect of SO_2 and NO_x on susceptibility to respiratory illness.

10. Particulate morphology as a function of collection techniques.

11. Ultra-low volume insecticides research.

Point of contact: Mark Chatigny (415)832-6343.

Naval Missile Center (NMC), Pt. Mugu, California

Two items were uncovered at NMC:

1. A TiO_2 0.55μ particle generator capable of generating pounds per minute.

2. An automobile exhaust scrubber.

The particle generator which was transferred to NERC-RTP is described elsewhere in this report.

The auto exhaust scrubber replaces resonator, is made of PVC, outlasts the exhaust system, and only costs about $25.00 to make (by hand). The system boosts gas mileage (4 to 8 miles per gallon) because it eliminates the smog pump and some other anti-pollution devices. The only maintenance is replacement of the strainer about every 6 months. Tests for CO and CO_2 output showed no measurable (on gas station equipment) output. Also, when the scrubber is placed on cars with bad rings, the visible oil smoke in the exhaust is completely eliminated.

EPA should be made aware of this invention. It can be easily tested and evaluated by EPA, and it would excel over the platinum catalytic converter.

Points of contact:

Steve Mallonee, particle generator, and Everett Rowe, auto exhaust scrubber: (805) 982-7192.

Naval Civil Engineering Lab (NCEL), Port Hueneme, California

In its two environmental protection groups, NCEL has 40 professional engineers and scientists, plus technicians and support personnel. Five specialty teams monitor and analyze noise, source emissions, air quality, land and water pollution, and conduct reconnaissance surveys of Naval activities for pollution sources and intensity. Other areas of environmental expertise cover solid and liquid waste disposal, ship sewage transfer, beach oil spill cleanup, oily waste treatment, and environmental data collection, storage and dissemination.

On 7 August 1973 the Navy Environmental Protection Data Base (NEPDB) was formally defined. Air monitoring programs were initiated in FY75 and increased annually toward full monitoring capability in 1978.

A return visit to NCEL would have been beneficial after significant implementation of air programs has been accomplished.

One of the most useful documents published in the field of pollution comes from NEPDB at NCEL (now just NEL) - a directory of contacts within the Navy, Army, Marine Corps, Air Force, Coast Guard, EPA, Department of Commerce, and U.S. Geological Survey who are cognizant over specific pollution areas.

Point of contact: Dr. Sam Brainin, head, NEPDB office: (805)982-5721.

Naval Postgraduate School, (NPGS), Monterey, California

A review of the research programs at NPGS revealed only one recent project relating to air pollution and a final report has not been published. This project characterized air stream patterns for dispersion of aerosols and methods of controlling pollutant emissions. However, capabilities are strong in the meteorological and computer science areas with an IBM 360-67, low velocity wind tunnels, instrumentation, and lasers. Dr. Haltiner, head of meteorology, is on the Monterey County board for air pollution control. (Navy Weather Central is located at the NPGS, also).

Dr. Gaver, head of the Operations Research Department, suggests a strong capability in dispersion modeling and analytical techniques exists at NPGS.

The willingness of those interviewed to assist NERC-RTP in any way they could was virtually unparalleled in my contacts with other laboratories.

The central point of contact is Dr. James Jolly, (408) 646-2691.

Naval Weapons Center (NWC)

Significant capabilities exist at NWC of interest to EPA. These include:

1. Atmospheric and weather modification research.

2. Remote and three-dimensional ambient air quality measurement devices using airplane and van as platforms.

3. Polarigraphic measurements of trace toxic and hazardous materials in water.

4. Environmentally-controlled aerosol test chamber for generating aerosols and testing effects of control variables.

Apparatus available include a variety of systems for collection, sizing and identification of particles and droplets in the atmosphere, remote optical and electromagnetic sensors for monitoring of such materials, and an extensive array of ground-based and airborne meteorological sensors. Resolution down to 0.046 Å is available. Additional capabilities include:

1. X-ray diffraction techniques for correlating particulate matter to its source.

2. Aerosol generation of metal oxides, sulfides, etc., short term or continuously for up to 16 hours with stable output.

Details of these capabilities follow:

1. The Environmental Studies Group uses an instrumented airplane (twin engine Cessna) and a mobile van, both of which continuously monitor various atmospheric parameters and pollutant concentrations. These parameters are recorded on magnetic tape which is processed on a Univac 1108 computer.

2. More sophisticated data analysis techniques such as X-ray fluorescence, electron microscopy, and atomic absorption will be used in on-going projects -- two of which are a Navy funded Range Visibility Study and an Air Force funded study of solid rocket motor exhaust.

The mobile van monitors (continuously):

1. Temperature.
2. Humidity.
3. Wind direction and speed.
4. Visibility (Nephelometric).
5. Ozone concentration.
6. CO concentration.
7. NO or NO_x concentration.
8. Condensation nuclei.

The airplane continuously can monitor:

1. Aircraft position and altitude.
2. Temperature.
3. Humidity.
4. Turbulence.
5. Visibility (Nephelometric techniques).
6. Ozone concentration.
7. CO concentration.
8. NO or NO_x concentration.
9. Condensation nuclei.

The NWC probably contains the most significant air pollution monitoring and control technology base in the Navy.

The central point of contact for tecnnology transfer is George Linsteadt, (714)939-7325.

Naval Surface Weapons Center (NAVSURFWPNCEN)

NAVSURFWPNCEN, Dahlgren Laboratory (DL) (formerly the Naval Weapons Laboratory) was awarded the task of fabricating a mobile scrubber under IAG 133D. This task is being performed separately from Task 1 of the agreement; therefore, it will not be covered here.

NAVSURFWPNCEN, White Oak Laboratory (WOL) (formerly the Naval Ordnance Laboratory) has technology available in air pollution monitoring and control in the area of aerosol size distribution determination. Studies of particulate control can also be conducted here.

Theoretical and experimental studies in particulate generation, filtering, and particle mechanics (all treated as fluidmechanics) have been conducted at NAVSURFWPNCEN (WOL) including:

1. Theoretical studies to determine aerosol-concentration distributions and deposition flux of dilute aerosols suspended within turbulent gas flows. Consideration was devoted to the effects of particle agglomeration and to the influence of electrical forces on the particle deposition behavior.

2. Experimental measurements of gas constituents concentrations by the use of a laser Raman spectroscopy. Experimental investigations of the fluid properties of a high-speed rotational flow have been carried out, also.

The Laser Doppler Velocimeter (LDV) developed by Dr. W. Yanta (202)394-2093, can measure particle size distributions in the 0.3 - 5 μ range. Recent work with the system (see Appendix B) proves the LDV to be a valuable laboratory tool for rapidly generating particle size distributions of low density aerosols.

Point of contact, technology transfer: Dr. Sherman Gee (202)394-2264.

Naval Research Laboratory (NRL), Washington, D. C.

In addition to a substantial involvement in water pollution research, NRL has the following capabilities:

1. Aerosol generation and filtration (Harold Bogardus).
2. Gas sampling and monitoring (Walter Faust).
3. Micro-particulate sizing and flow (Felix Rosenthal).
4. Sample characterization (cyclotron) (Clarence Bond).
5. Asbestos characterization and structure of gaseous and particulate matter (Jerome Karle).
6. Sea-air interactions.
7. Effects of pollutants on photosynthesis.
8. Water vapor measurements in the stratosphere.

Work in aerosol filtration conducted as part of Task 1 is described elsewhere in this report.

NRL's expertise to attack pollution monitoring and control problem is among the most significant within the Navy laboratory complex.

Central point of contact is Robert Seebold, (202)767-3083.

Naval Ship Research and Development Laboratory, (NSRDL), Annapolis, Maryland

NSRDL, aside from its basically military tasks, is primarily involved in water and solid waste pollution problems. However, some work is on-going in air problems related to particulate emissions and SO_x and NO_x from ship stacks, as well as particulates, CO_x, and aerosols aboard the closed environment of submarines.

NSRDL's Pollution Abatement Division consists of approximately 30 people. Major areas and contacts are listed below:

1. Air Pollution from Navy Ships: B. Wallace
2. Air Pollution within Submarines: J. S. Post
3. Navy Data Base Programs: G. B. Nickol
4. Water Pollution: J. I. Schwartz
5. Thermal Pollution: W. Adamson
6. Solid Wastes: P. Schatzberg
7. Liquid Wastes: W. VanHees

The central point of contact is Mr. Isadore Cook, (301)227-1852.

Army Laboratories

Army Cold Regions Research and Engineering Lab (CRREL), Hanover, New Hampshire

A unique capability possessed by CRREL is the analysis of ancient air samples, preserved in glacial ice in Greenland. SO_4, Pb, etc., levels are determined as well as the oxygen isotope ratio. Dr. Chet Langley is currently heading the effort.

The CRREL's liquid waste processing pilot plant outflow is pathogen-free and drinkable. Green plants aide in leeching out chemicals they can use as nutrients.

The CRREL is also involved with studying lake pollution with satellites, fog dispersal and creation, and air "sniffing" for hydrocarbon content.

Although mentioned very briefly above, CRREL capability in their areas of expertise appears to be unsurpassed. Dr. Andrew Assur, Chief Scientist (AC (603)642-3200, X237) is the technology transfer contact at CRREL.

Army White Sands Missile Range, White Sands, New Mexico

Several projects and technologies pertinent to EPA requirements are available at White Sands, including:

1. Particulate characterization (down to less than .05µ).

2. Dry aerosol generation (1 - 10 grams/meter^3 concentrations).

3. IR spectrometry.

4. Dust sampling (world wide).

5. Optical degradation due to pollutants.

6. Nephelometry.

7. Chemical analysis (wet).

Work at White Sands in these areas has not had the visibility that related work at other DOD laboratories has had; nonetheless, it appears to be at high quality.

Details of the particle characterization capability include:

1. Single particle resolution (.05µ diameter) in an atmosphere using a mercury arc lamp.

2. Homemade laboratory device, but can be engineered for the field. A report is in preparation.

3. Output yields shape information, size, and identification.

4. Possible, in conjunction with computer program, to analyze 1000's of particles per second, in real time.

5. Forward and two simultaneous right angle scattering plus photon counting gives a dynamic range of from DC to 10^8 (10^4 better than existing commercial devices).

The Optical Properties of Atmospheric Particulates Group perform IR and near IR spectrometry. Using diffuse reflectance and photometric techniques it is possible to obtain the absorption coefficient of samples. Discoveries include a 10^3 higher coefficient than previously thought for dust (due to carbon and iron particles in small concentrations). These are currently able to generate synthetic dust and (possibly) fly ash. A project is underway that will sample dust all over the world (using Bendix equipment). It should be completed before the end of this year. A world wide soil sample project is now winding up, using an integrating spectrometer. Also, the group is working on nailing down optical degradation due to pollutants in the atmosphere considering diffuse reflectance rather than transmittance as the criteria.

Also available at White Sands are sensitive nephelometers. These nephelometers measure water drops (size and shape and distribution) in the 2.5 - 250μ (radius) range. Slight modification to their equipment would enable them to go down to 0.3μ. They use an HeNe laser at night.

They consider the effects of water "pollution" in air to be:

1. Increase in coalescing.
2. Collision effects.
3. Electrical effects.
4. Sound alterations.
5. Improved scrubbing efficiency.
6. Adherence of water to solid pollutant particles.
7. Difficult to monitor dry particles that get wet.

White Sands feels they have an almost unique capability of addressing these effects.

The central point of contact in the Atmospheric Sciences Laboratory is Glenn Hoidell, (915)678-2926. Other knowledgeable people include:

Light Scattering Particle Analyzer	Mr. W. J. Lentz
Optical Properties of Atmospheric Particulates	Mr. J. Lindberg
Fog Nephelometer	Mr. R. Loveland Mr. D. Dickson

Army Land Warfare Lab (LWL), Aberdeen, Maryland

Between the visit arrangements and the actual visit, LWL received notice of phase-out and shutdown. Therefore, no capability to perform work at LWL exists. Their strongest capabilities of interest to EPA (IR remote sensing of particulates and real time mass spectrometer techniques) were transfered to Edgewood Arsenal.

However, because of the lab phase-out, it was possible to obtain a General Electric Condensate Nuclei (CNC) counter, two Nolan CNC standards, and a GE particle generator for further transfer to NERC-RTP. These equipments are described in more detail elsewhere in this report.

Dugway Proving Grounds (DPG)

Dugway capability is primarily in environment control. Specifically, the generation, measurement, tracking, collection and analysis of fine particulate aerosols in low concentrations over long distances constitute a significant effort at Dugway.

For the past two decades Dugway has conducted extensive studies in identifying, measuring and monitoring chemical and biological materials in the atmosphere and in developing mathematical techniques to characterize their transport and diffusion in these media. Field studies have been conducted at remote locations throughout the world to extend knowledge of airborne material behavior in a variety of meteorological regimes.

Specifically, the technologies and capabilities possessed by Dugway in these areas include:

1. Development of analytical techniques for pesticides or process waste components.

2. Development of instrumentation to measure trace contaminants from mixed waste streams.

3. Biological research of processes utilizing living organisms and their by-products.

4. Sampling and analysis of particulate and aerosol clouds.

5. Tracer studies to characterize an emission source including the development of diffusion and transportation models to define their travel.

6. Conduct of ecological field studies to define the effects on the total environment as a result of a specified operation.

7. Conduct of field studies requiring large numbers of remotely controlled samplers followed by automated processing of large numbers of resulting samples for analysis.

8. Tests of objects or devices under a wide variety of programmable controlled environmental conditions.

9. Tests requiring a complete integrated facility to be established on site (characterization of a pollution source,

utilizing tracers and requiring extensive field sampling and sophisticated meteorological field measurements).

10. Particle generation (1-5μ).
11. Bio-denitrification using anarobic bacteria.
12. Waste water treatment.
13. Stack monitoring.
14. Marine aerosol particulates research.
15. Spray systems evaluation.

An extremely broad system of facilities is necessary to support the broad spectrum of capabilities exhibited by DPG. The following is a partial compilation of facilities useful for pollution studies.

1. Chambers

Over 20 chambers of various sizes up to 50' x 30' x 20' are available, with a capability for a wide range of programmable environmental conditions from arctic to desert, tropic to cold, salt fog to rain, and low pressures to sand and dust.

2. Filter Tests

Two penetrometers are maintained for the purpose of measuring the penetration and life of filters. The penetration is measured by passing 0.3 micron smoke through and measuring the degree of penetration.

3. Atomic Absorption Spectrophotometer

The Model P-E 303 is an analytical flame instrument which is used to determine the trace metal content of a sample. This technique appears to be the most reliable and rapid means for detecting and analyzing metals.

4. Robot Chemist Analyzers

This instrumentation is used for colorimetric/spectrophotometric analyses for which time and/or temperature control is critical. Its main use is in the analysis of trace quantities of chemicals. For example, methyl acetoacetate may be analyzed over the range 0 to 1 μmg/ml, with a lower detection limit of less than 0.1 μmg/ml. Because of the time and temperature controls, this instrumentation is ideally suited to the enzymatic assay of trace quantities of some chemicals down to less than 0.001 μmg/ml.

5. Sampling Hardware

Over 8000 samplers of various types include large numbers of all the conventional samplers such as all glass impingers (AGI's), Anderson particle size discriminating samplers, Reynier slit samplers, Rotorod fluorescent particle samplers, Millepore filter samplers, chemical bubblers, chemical impactors, Snoot filter samplers, Cascade Impactor samplers, and filter paper and printflex card samplers. Various combinations of sampling sequencing are accomplished by using such units as the radio-controlled sampler. For special testing the Large Volume Air Sampler (LVAS) is used. A limited number of more specialized samplers used at DPG include the Microaerofluorometers (MAF's), Royco particle counter, and Space Charge Atmospheric Precipitator (SCAP). Quantitative vapor and droplet data can be obtained on particle sizes below 5 microns and above 100 microns. Mass quantity can be determined for the intermediate size range. Particulate matter in the size range of 0.5 microns to 15 microns has been the range of interest in DPG testing, hence expertise and capability are concentrated in this area.

6. Automatic Data Acquisition System (ADAS)

DPG has two ADAS each of which consists of a data central collection terminal housed in an air transportable mobile van. Each van can control up to 24 low data rate remote stations and 12 high data rate remote stations. Data is telemetered from the remote stations via simplex RF links to the central terminal. Each remote station can handle up to 64 sensors, 254 of which can be sampled at the rate of 10 times per second and the remaining 40 at the rate of once per second. Data is telemetered from the remote station via simplex RF links to the central terminal.

7. Meteorological Facilities

a. DPG has extensive meteorological facilities for the measurement and display of weather phenomena on the micro scale or the macro scale. Meterological tests are performed to develop and/or prove model theory and to support testing.

b. A USAF-operated weather station is located at DPG. This facility serves as an important element of weather services coverage in the Western United States. Facilities associated with this service include an FPS-77 weather radar, a direct line radar facsimile to the U. S. Weather Bureau in Salt Lake City, a Rawinsonde facility, and a national weather facsimile and teletype system.

c. By mutual arrangements with the U. S. Weather Bureau (ESSA) and the FAA, the DPG system is combined with the ARTC radar network in a weather surveillance program which provides weather radar coverage for the Western United States. The product is a composite summary of precipitation echoes from up to 22 radar stations in the Western United States. This product is transmitted hourly, on the hour, only 15 minutes after the time of observation. The transmitted chart gives location, type of precipitation (snow, rain, thunderstorms, etc.), and an estimate of the intensity of the precipitation (this includes direction and speed of movement of the precipitation echoes). These charts are exchanged on a hot-line facsimile circuit between Salt Lake City, FAA facilities, and DPG. In addition to this system of filling the gaps to extend effective radar coverage of the FPS-77 radar at DPG, operators can communicate directly for additional information concerning specific echoes so as to enhance this capability.

d. The combined DPG meteorological data systems (in terms of the total number of meteorological sensors), the area covered by the sensor networks, and the total data acquisition and processing capabilities comprise the largest automated fixed point system in the United States.

7. Life Sciences Laboratories

a. The Life Sciences Laboratories encompass a broad spectrum of activities in biology, microbiology, biochemistry, toxicology, and fluorescent tracer studies. Its physical facilities include research laboratories, for field testing, ecology, epidemiology and toxicology as well as breeding and rearing units for small laboratory animals and for selected species of native fauna. Also, the facilities serve as holding units for small and large experimental animals including cattle and horses.

b. The capabilities are characterized by mobility since they were developed not only for testing at Dugway but also for operations at distant sites. Moreoever, they are also well-suited to various nonmilitary applications such as studies of environmental pollution in air, soil, and water (and steps required for pollution abatement); investigations in the general area of medical microbiology and medical aerobiology; research in the toxicology of pesticides; meteorological studies and tracing of the movements of masses of water through the ability to select, sample, and assay suitable physical tracers; and for research in mammalian and microbial biochemistry.

c. Devices in the laboratory permit the generation and holding of confined aerosol clouds under closely controlled conditions and over a wide span of temperatures and humidities. Laboratory studies of samplers, collecting fluids, culture media, and assay techniques can thus be performed with aerosols that are a reasonable approximation of those generated in the field. It is possible to study the effects of environmental conditions on contained aerosols for comparison with changes found in the open air and to conduct animal exposure studies.

d. Recently, these aerosol facilities have been supplemented by a series of other items designed for specific purposes. Among these are a large-diameter duct for work with dynamic aerosols at ambient temperature and humidity; multi-channel particles size analyzers, a spinning-disc particle generator with static eliminator; submicron aerosol generators; ozone generator and ozone, nitrogen oxide, and sulfur dioxide analyzers, for the study of the effects of air pollutants on the survival of airborne microorganisms. Animal exposure facilities, an integral part of the installation, permit such studies as testing the effect of air pollutants on animals.

e. A completely new capability, the microthread technique, consists of depositing micron-sized aerosol droplets of biological materials under closely controlled conditions in an enclosure on extremely fine stainless steel wires held on frames. Thereafter, the frames containing the coated wires may be exposed to any desired environmental conditions to study the effect of factors such as air pollutants, relative humidity, temperature, and solar irradiation on the survival of microorganisms. In this way, properties of captive aerosols may be studied outside chambers. The usefulness of this approach may extend to the detection and abatement of air pollution.

f. Greenhouses are used in toxicological studies involving plants and permit growth of indigenous plants and feed crops throughout the year on a limited scale. Their usefulness in environmental and pollution studies is evident.

g. Aside from the skill and equipment to perform virtually any type of microbial assay, a complete capability for fluorescent particle tracer work exists; this ranges from evaluation of new and conventional types of phosphors, through evaluation of powder fluidizers, testing and quality control of fluorescent pigments, to the assay of field samples by procedures maintained under tight quality assurance of data. Soluble fluorescent tracers can be assayed with exceptional sensitivity by special methods (in some cases, at the sensitivity of parts per 10 billion level). Such tracers are useful in many ways, for example: (1) to delineate aerosol clouds; (2) to permit elimination of negative sampling stations so as to diminish assay expense; (3) to aid in studies involving determination of biological and physical decay of aerosol clouds; and (4) in meteorological and environmental pollution studies. These substances have been used to study the hazards of secondary aerosols created in biologically-contaminated areas, and they could be used to determine analogous hazards in hospitals. They have recently been applied for testing of the efficacy of particulate filters, and initial work has shown the feasibility of their use in devising appropriate methodology in the use of insecticides in various environments.

h. The central point of contact at Dugway for these technologies is Mr. Vic Pratt, (801)522-2914.

Army Construction Engineering Research Laboratory
Champaign, Illinois

CERL is the Army Corps of Engineers' central laboratory for pollution monitoring and control technology, just as Edgewood Arsenal is the central laboratory in the Army Material Command.

CERL is approaching pollution monitoring and control from an interdisciplinary angle. They are charged by the Army to assess technology of stack emissions (gaseous and particulates) from Army installations. This is a function analogous to that of McClellan Air Force Base.

The Environmental and Energy Systems Division conducts research relating to solid, liquid, and gaseous pollutants, as well as technology of energy. One major area of thrust has been the development of design criteria for treating wastewater, controlling NO_x, and sludge disposal. Also, this division has established baseline data for characterizing waste from Army facilities to determine the Army's potential for polluting the environment and techniques required for controlling and reducing such pollution.

CERL enjoys the advantage of affiliation with the University of Illinois.

Points of contact are:

Dr. G. Rigo, overall: FTS (217)356-1151
Walter Mikucki, Environmental Engineering: AC (217)352-6511

Edgewood Arsenal

Edgewood Arsenal is the largest center of chemical research and development within DOD. It is an installation consisting of 10,000 acres of land and about 5.5 million square feet of building space.

One of Edgewood's current missions is to detect, identify, and measure trace quantities of contaminants in air, food, soil, tissues and on all types of surfaces is directly applicable to environmental studies. Currently, Edgewood is the Army Material Command's lead laboratory for Pollution Abatement and Environmental Control. Also, Edgewood is involved in studies to determine how pollutants are transmitted through the eco-chain to man.

Environmental pollution control is a major function at Edgewood. In addition to extensive facilities and expertise in water and solid waste problems (air will be discussed at length, presently), Edgewood is involved in interface areas, such as the incineration of hazardous liquid wastes and its impact on air pollution. The effects of pesticides on the environment is also an area of expertise for Edgewood.

Edgewood has the capability to design and develop instrumentation for environmental monitoring. Research into the application of chemical agent detectors and alarms for detection of air and water pollutants is underway, as are projects concerned with gas and aerosol cloud meteorology and micrometeorology.

An extensive capability in veterinary medicine is available at Edgewood for the purpose (among others) of establishing the effects of environmental pollutants on living systems.

A considerable body of knowledge and unique experience is available in the design of specialized filters for the removal of gross and trace quantities of vapors and aerosols. This includes the development of specialized test techniques to evaluate the performance of filters. Leakage determination can be made in the parts-per-billion (ppb) range for aerosols, and near the nanogram per liter range for vaporous contaminants. Special filters and mountings can be designed for virtually any application and capacity desired. Edgewood's sorptive charcoals and absolute air filtration systems have been adopted as international standards.

Other methods of air purification than mechanical filtration and sorption have been investigated at Edgewood, including electrostatic precipitators for particulates and thermal and wet scrubbing techniques for vapor contaminants. Extensive studies in fibrous roughing filters and bag filters have also been performed for aerosol and dust removal.

Edgewood has developed and evaluated data which have resulted in mathematical models of atmospheric behavior. The models take into account the nature of the source (geometry, time of release, etc.), the nature of the pollutant released and predict the resulting space and time variations in concentration. These models form the basis for predicting the hazard from potential pollution sources. Analysis of the predicted behavior of potential or existing pollution sources will indicate the extent of the hazard and the degree of air pollution control which will be required to correct the problem. Edgewood studies of atmospheric behavior chemical agent deployment are directly applicable to the transport diffusion, fallout, interception and sorption of air pollutants in the environment. This capability in aerodynamic investigations extends to subsequent effects on the ecological system and includes solid, liquid and gaseous states.

An extensive computer facility is necessary to support the above model. The 1108 is available to EPA as well as such services as the automatic calculations of volumes, surfaces, centroids, and other assorted shapes. Uses of this service can include calculating mapped areas for ecological studies and analyzing spectral data for atmospheric pollutants.

Other facilities and capabilities at Edgewood include:

1. Active and Passive LOPAIR (Long Path Infrared) detectors.
2. Remote Raman Chemical Detectors.
3. CO_2 Laser Chemical Vapor Detector.
4. Chemical Detectors and Alarms.
5. Enzyme Chemical Detector and Alarm.
6. Fluorescent Pollutants Detector Kit.
7. Arsenicals in Water Sampler.
8. Chemical Samplers.
9. Ionization Detectors.
10. Chemical Vapor Concentrator.

Passive LOPAIR study models indicate that low angle sky infrared energy can be used to detect and monitor the intervening path for the presence of pollutants. Similarly, the CO_2 laser LOPAIR may be useful for remote low angle sensing of impurities.

The remote Raman System also offers promise for the remote sensing and monitoring of atmospheric pollutants.

Extensive reference files of infrared, ultraviolet, Raman, laser Raman, visible, atomic absorption, emission and mass spectra have been accumulated at Edgewood.

Edgewood's analytical chemistry effort is aimed at developing methods for qualitative and quantitative analysis in the parts-per-billion area and ranging up to tons. A number of advances in high volume sampling have been made for monitoring extremely low concentrations of air pollutants and chemical agents. Devices have been designed and tested for collection efficiency at sampling flow rates up to 200 liters per minute. One device, based on the venturi principle, shows a collection efficiency greater than 75% at 100 liters per minute. Air concentrations of chemical agents in the order of .0003 mg/m^3 can be determined within 5 minutes, continuously and automatically. The venturi scrubbers device can be used for monitoring stack emissions.

Twenty-three exposure chambers, two wind tunnels, aquaria, and climatic facilities to produce any global condition give Edgewood the capability to sample, analyze, characterize, and evaluate the hazard resulting from virtually any industrial chemical, waste product(s), or natural products. In addition to a large low velocity wind tunnel capable of holding several people, Edgewood has a subsonic wind tunnel, 14 by 20 inches, with a test section 3 feet in length, and a 14 by 20-inch cross section, capable of speeds from 15-300 miles per hour. Also, a subsonic wind tunnel, 28 by 40 inches, with an open circuit straight settling chamber tunnel, capable of speeds from 25-160 miles per hour.

The types of field instrumentation developed at Edgewood Arsenal are directly applicable to continuous use as environmental monitoring systems since they give immediate read-outs of the results. An outdoor, instrumented test range with concentric sampling grids is available for monitoring airborne pollutants.

Work has been done at Edgewood on the destruction of chemicals by incineration. This was accomplished by actual burning of toxic chemicals in a pilot scale incinerator with complete collection and identification of the stack emissions.

Edgewood Arsenal's capability in air pollution abatement and control technology is directed to developing bench scale techniques to recycle, reuse, reduce in volume, treat or dispose of all types of pollutants. The pilot plant effort scales up the laboratory techniques to working models. Together, there exists a strong capability to investigate the spectrum of environmental abatement and control technology.

Contacts at Edgewood include:

Dr. John Stevens and Dr. S. R. Eckhaus, overall: (301)671-3133/2347

Dr. L. A. Jonas, Chemistry: (301)671-3753

Dr. Ira Abelow, Scrubbers, Particulate collection, Asbestos detection: (301)671-4251

Dr. S. Love, Ionization detection, Real time monitoring: (301)671-3971

Dr. B. P. McNamara, Low velocity, Wind tunnels, Aerosol generation: (301)671-3034

Dr. Leonard Jones, Bag filters: (301)671-3753

Dr. Bernard Gerber, Particulates: (301)671-3757

Appendix B

Dielectrophoretic Filtration of Aerosols

G. H. Fielding, H. F. Bogardus
R. C. Clark and J. K. Thompson
Naval Research Laboratory, and
E. A. Byrd
Naval Surface Weapons Center

Introduction

Dielectrophoresis is an electrical mechanism which shows considerable promise for air filtration technology. It can be used to augment the performance of high-quality commercial glass fiber filter media. This augmentation is typically by 10-fold or more. Dielectrophoresis makes no change in the filter medium and does not affect the pressure drop in the filter. Although it requires high voltages, it uses almost no current or power; hence power supplies can be small and inexpensive. Dielectrophoresis produces no ozone or electrical corona and function whether aerosol particles are charged or not. That is, it does not depend on coulombic attraction between charged particles and surfaces of opposite polarity; it is not electrostatic precipitation. In spite of this array of favorable characteristics, dielectrophoresis is as yet almost completely unknown to air filtration applications.

An uncharged aerosol particle within a homogeneous electric field is polarized by the field, but is not subject to any displacing force due to the field. If, however, there is placed in the field a foreign body, such as a filter fiber of material whose dielectric constant is greater than one, the field becomes distorted due to polarization of the fiber. Surrounding the fiber there is a resultant field gradient with intensity increasing toward the fiber surface. An uncharged but polarized aerosol particle entering such a region of inhomogeneous field intensity, i.e., toward the fiber surface, may be captured. This dielectrophoretic effect described for a single fiber is multiplied many times for a fibrous filter medium placed in an electric field. Every interfiber space in the filter mat becomes a microscopic region of field inhomogeneity in which dielectrophoresis can occur. Dielectrophoresis in filtration occurs concurrently with and in addition to the usual mechanisms contributing to aerosol deposition, namely, interception, inertial impaction, and diffusion.

The theoretical aspects of dielectrophoretic filtration have been extensively treated (1-13). Hence, NRL effort emphasized seeking a practical and economical application of dielectrophoresis to improve the performance of existing commercial filter media. A simple configuration has been used in which the electric field is impressed parallel to the direction of air flow.

Dielectrophoretic movement of aerosol particles in a glass fiber air filter occurs when metallic screen electrodes, placed on each side of the fiber mat, are impressed with a high dc potential. The electric field polarizes all of the aerosol particles between the electrodes, but they acquire no net charge and are not attracted to either electrode. In the absence of the glass fiber mat, the field between the parallel screen electrodes would be essentially uniform, with the lines of force straight and parallel. When a glass fiber mat is located between the electrodes, the field around each fiber becomes nonuniform, with the lines of force tending to concentrate in the fibers. This effect is due to a dielectric constant, or permittivity, for glass which is greater than that for air. (The resemblance to the concentration of magnetic lines of force concentrating in a piece of iron is striking.)

It is clear that a glass fiber air filter in an electric field becomes a maze of field nonuniformities. As a field-polarized aerosol particle enters a field nonuniformity it is acted on by a force up the field gradient and toward the glass fiber (just as a piece of iron moves toward the higher dielectrophoretic force). It is independent of and in addition to the normal aerodynamic, inertial, and diffusional forces which act on each aerosol particle in a fibrous filter. Accordingly, dielectrophoresis is an augmenting rather than exclusive mechanism.

A unique and desirable feature of dielectrophoretic air filters should be noted at this point: the dielectrophoretic force is strongest when a particle is at or on the fiber surface. Thus the filter deposits are retained strongly by this filtration mechanism. This is in contrast with other types of air filters in which the filtration mechanism either no longer acts after a particle is captured or, more commonly, tends to remove it. Filters operating by the latter mechanisms must therefore depend for particle retention films deposited on the surface or on van der Waal's forces.

Filters

The filter media studied were of a type normally used for dust removal or for pre-filtration ahead of high efficiency filters. They were reinforced, nonwoven glass fiber mats 6.4 mm thick. Three grades were used; they differed from each other in fiber blend, packing density, and their resulting filtration capabilities. The filtration characteristics of these filters, as stated by the manufacturer (14), are shown in Table I.

Table I

FILTRATION CHARACTERISTICS OF GLASS FIBER FILTER MEDIA

Filter Medium	Pressure Drop	Air Velocity	5μ Dust	DOP Aerosol
HP-15	0.35 in. w.g.	44 cm/sec	99 %	Not rated
HP-100	0.40 in. w.g.	20 cm/sec	99.7%	60-65%
HP-200	0.40 in. w.g.	17 cm/sec	99.9%	80-85%

For experimental purposes a 14 cm x 14 cm section was mounted in a hardboard frame. This framed filter assembly was then sandwiched between two 20-mesh stainless steel screen electrodes.

The filter-electrode assembly was mounted between round-to-square transitions in the center of a cylindrical duct 10 cm in diameter by 250 cm in length. Air movement through the system was provided by a canister-type vacuum cleaner at the downstream end. The cleaner motor speed was controlled by a variable autotransformer. Air flow rate was measured by means of the pressure drop across a calibrated nozzle in the duct. Provision was made also for measuring the pressure drop across the filter. Current to the filter at 7kv impressed voltage is almost undetectable on a microammeter; it is estimated to be about 0.25 μa.

The polyurethane foam medium is noteworthy in that it is very cheap, can be either washable or expendable, has a very low pressure loss, can be assembled into multilayer foam-plus-electrode sandwiches, and can be pleated, folded, or adapted to a variety of other shapes.

The vinyl-coated glass multilayer screening also has some very attractive characteristics. The pressure loss is low, comparable with that of the foam, and about 1/5 that of the HP-100 medium. Further, we believe that it could be molded into a pleated or corrugated form. This would result in a rigid, self-supporting, fireproof, high temperature, very low pressure loss filter that could be washed with high-pressure water. Two or more electrodes could be spaced within the filter if desired.

First Experiments

Method

Aerosol was introduced into a plenum at the inlet end of the duct. Two liquid aerosols were used: (1) 0.3 micron-diameter dioctylphthalate (DOP) generated by a vapor condensation process and (2) nominal 1.0 micron-diameter DOP generated by an atomizer coupled to a jet impactor for removal of large drops. Aerosol concentration before and after the filter was measured with a light-scattering photometer. Each aerosol sampling point was preceded in the duct by a series of orifice plates for aerosol mixing.

A variable-voltage, positive-ground dc power supply was connected to the wire screen electrodes. This provided an electric field through the filter parallel to the direction of air flow. There was a small current, less than 0.25 microamperes, through this circuit which was attributed to leakage through insulation. The voltages applied were too low to generate a corona discharge between the electrodes. Had there been a corona, the current would have been of the order of a few milliamperes.

The experimental procedure involved the simultaneous measurement of filter penetration (or filter efficiency) and pressure drop in the filter at a number of voltages and air flow rates. Starting with the lowest flow rate, the unfiltered and filtered aerosol concentrations were measured first at zero voltage and then at successively higher voltages up to a maximum of 7 kv. This procedure was repeated as air flow rate was increased step-wise up to the maximum appropriate for the filter.

Results

The results of the initial dielectrophoretic filtration study are presented in Figures 1 through 6. Each figure shows the percentage of aerosol retained by the filter as a function of air velocity (or pressure drop) at applied voltages from 0 to 7 kv. For the 6.4 mm thickness of these filters the electric field through the filter (in kv/cm) was 1.57 times the applied voltage.

The effect of the applied electric field in enhancing filtration efficiency has been rated numerically by means of a calculated index called the Dielectrophoretic Augmentation Factor (DAF). This number is the ratio of the percent aerosol penetration (100% - % retention) at zero voltage to the penetration at the voltage of interest. For example, if a filter at a given flow rate showed a penetration of 10% at zero voltage and 1% at 7 kv, the DAF for that set of conditions would be 10. Values of the DAF are shown in Tables II through VII as a function of applied voltage for each air flow rate studied.

Discussion

Figures 1 and 2 show the aerosol retention by the HP-15 filter when challenged with 0.3 and 1.0 micron DOP, respectivley. HP-15 has a fairly open structure; hence, aerosol retention was relatively low. At zero applied voltage the aerosol retention increased as air velocity increased, indicating that inertial deposition is the controlling mechanism of filtration. With an electric field established, the characteristic curves show an opposite curvature. This shows that the longer the time that an aerosol particle remains under the influence of a field nonuniformity, the closer it can approach the fiber, and the higher is the probability of capture by the fiber. One might expect that at extremely high velocities the dielectrophoretic effect would be negligible compared to that of the inertial mechanism.

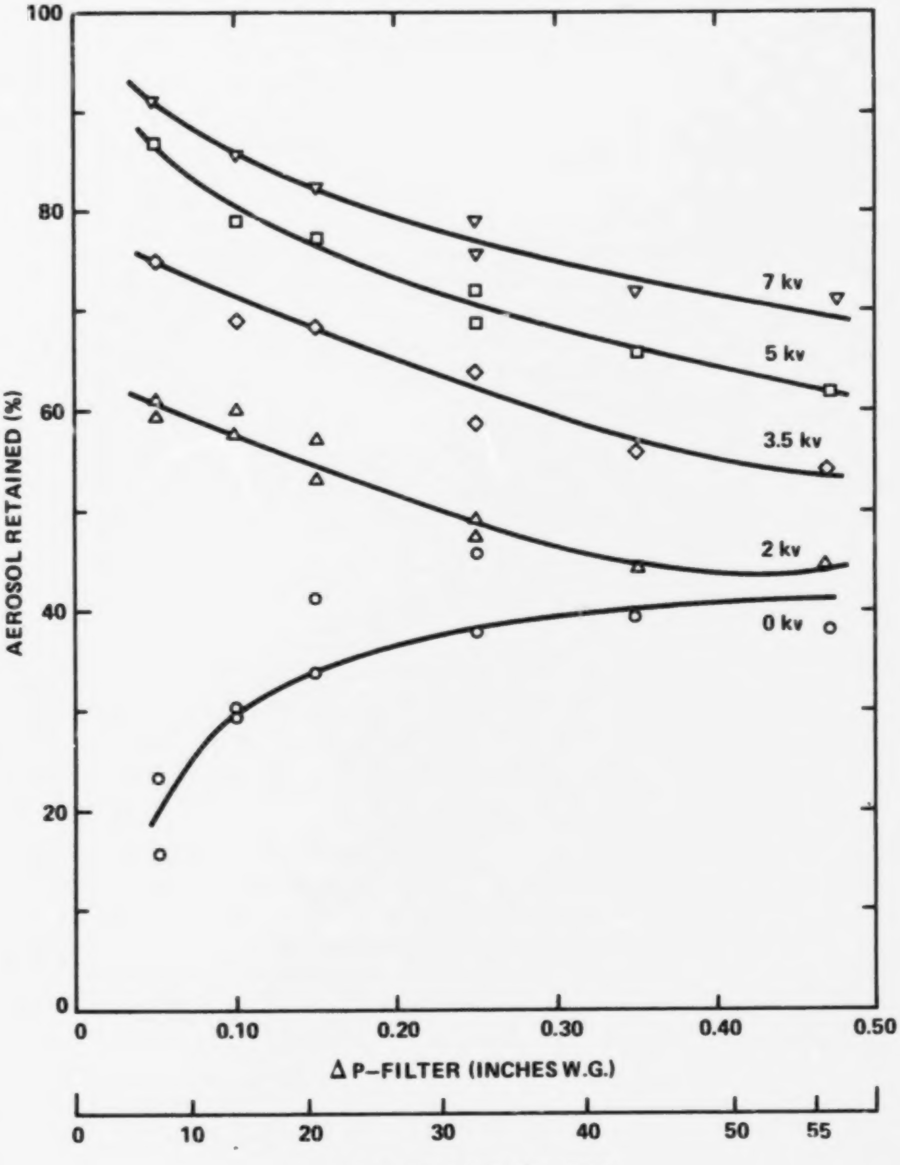

FIG. 1 INFLUENCE OF APPLIED VOLTAGE UPON RETENTION OF 0.3 MICRON DOP AEROSOL BY HP–15 FILTER MEDIUM

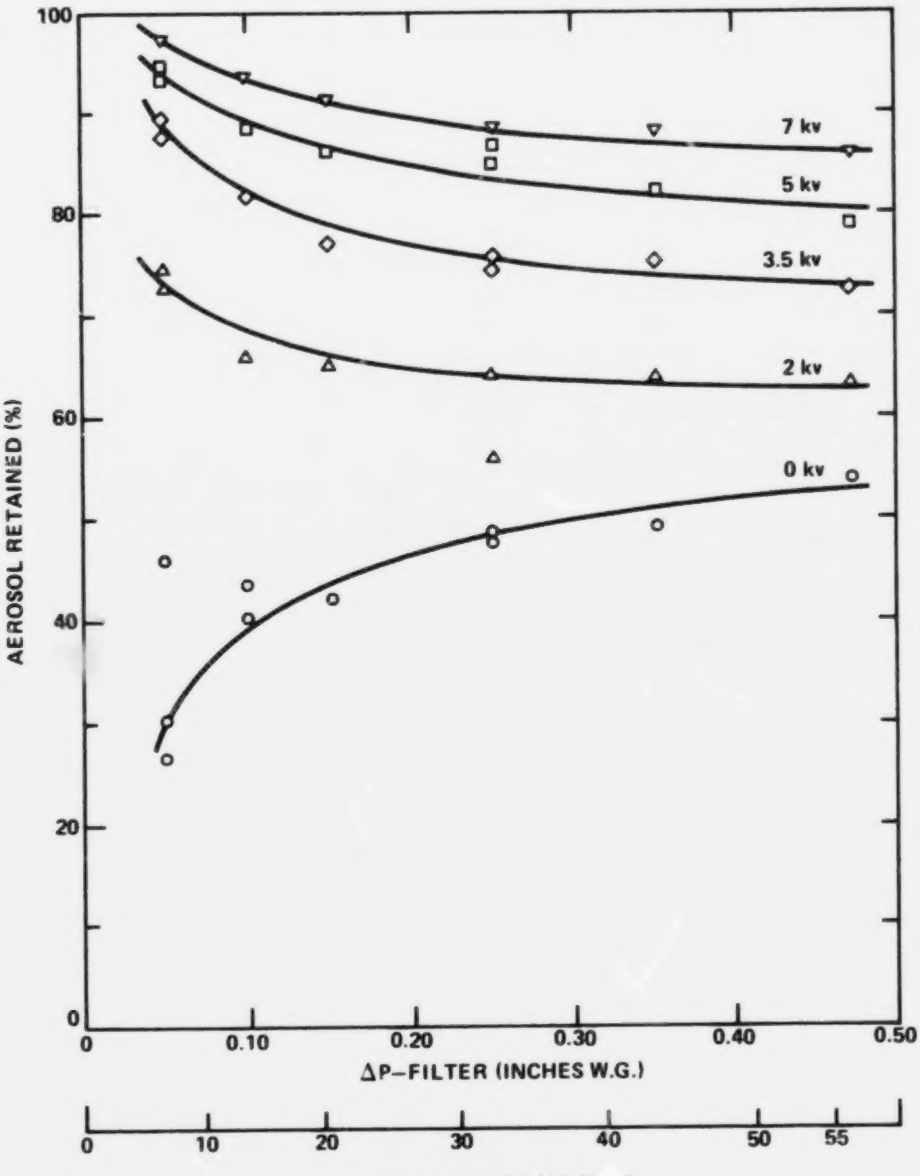

FIG. 2 INFLUENCE OF APPLIED VOLTAGE UPON RETENTION OF 1.0 MICRON DOP AEROSOL BY HP–15 FILTER MEDIUM

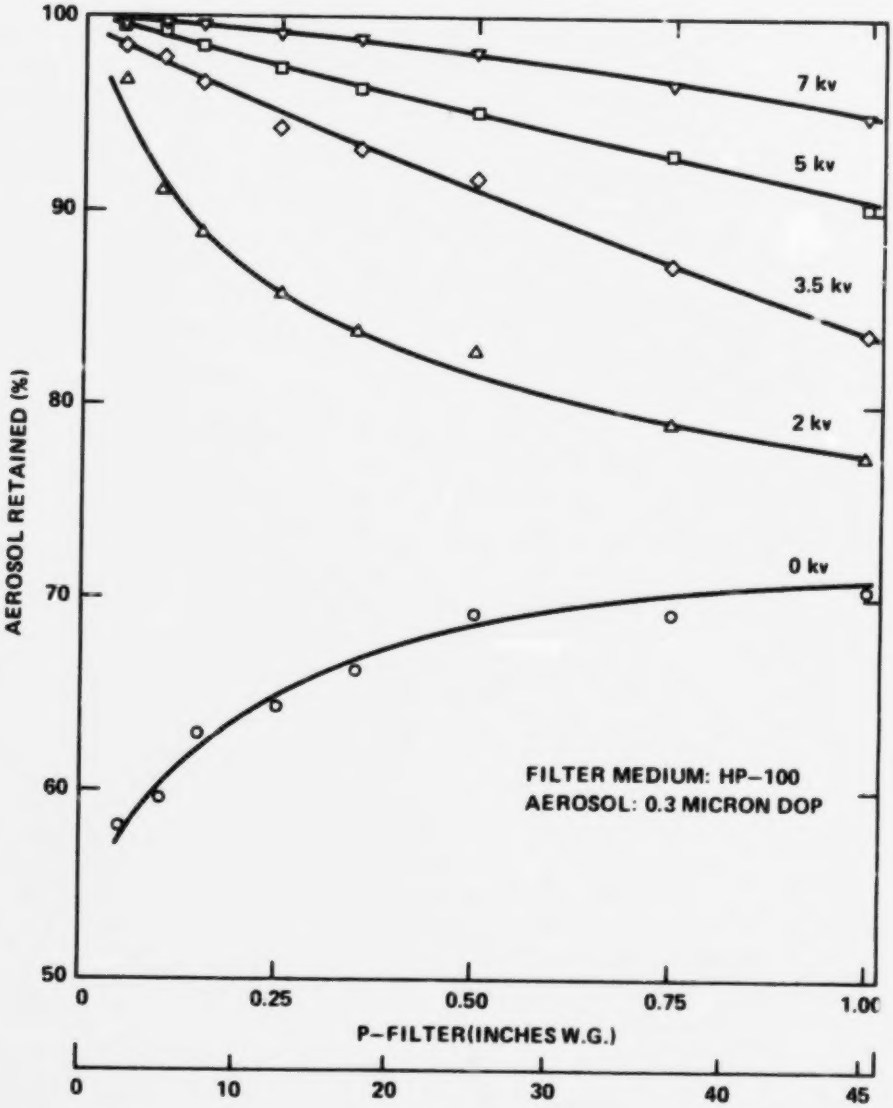

FIG. 3 INFLUENCE OF APPLIED VOLTAGE UPON RETENTION OF 0.3 MICRON DOP AEROSOL BY HP–100

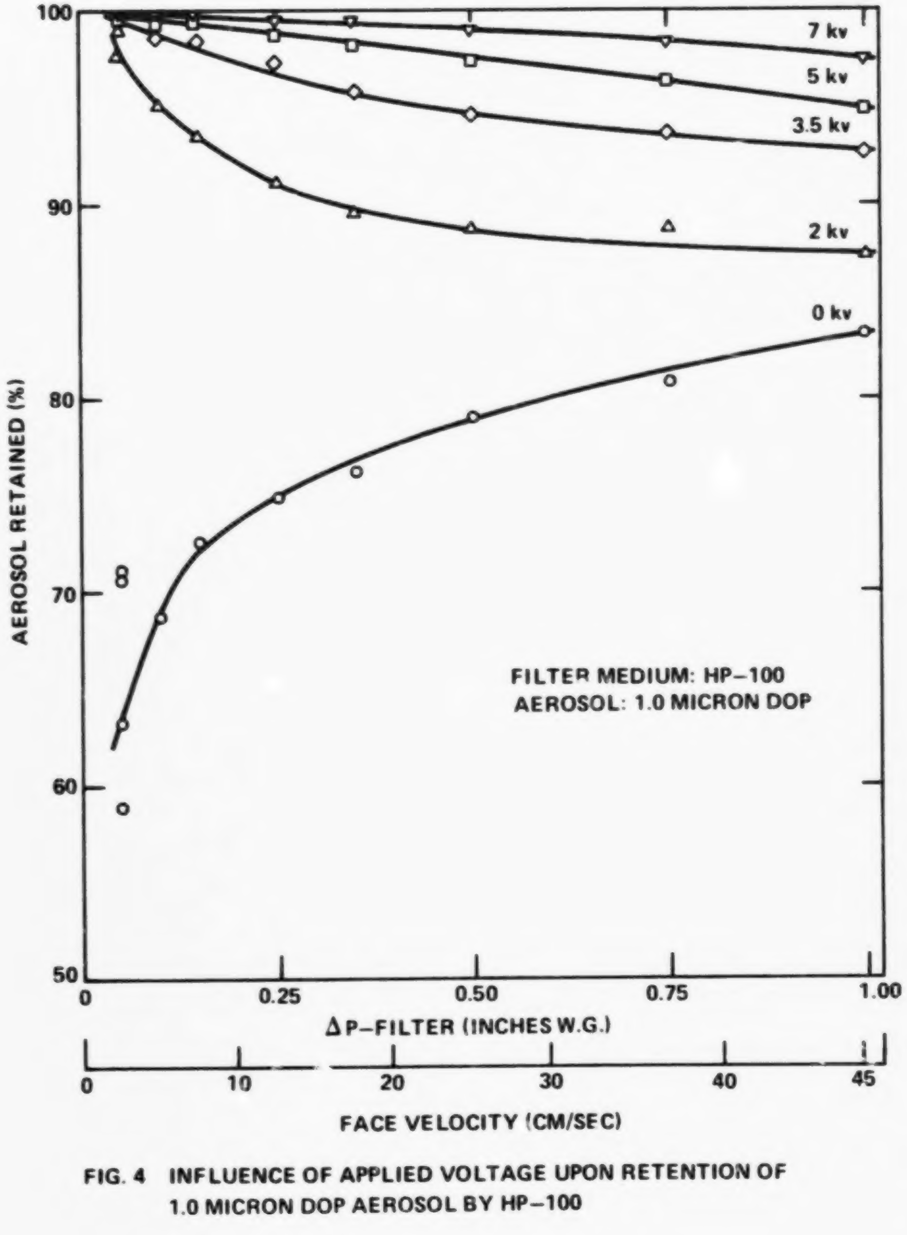

FIG. 4 INFLUENCE OF APPLIED VOLTAGE UPON RETENTION OF 1.0 MICRON DOP AEROSOL BY HP–100

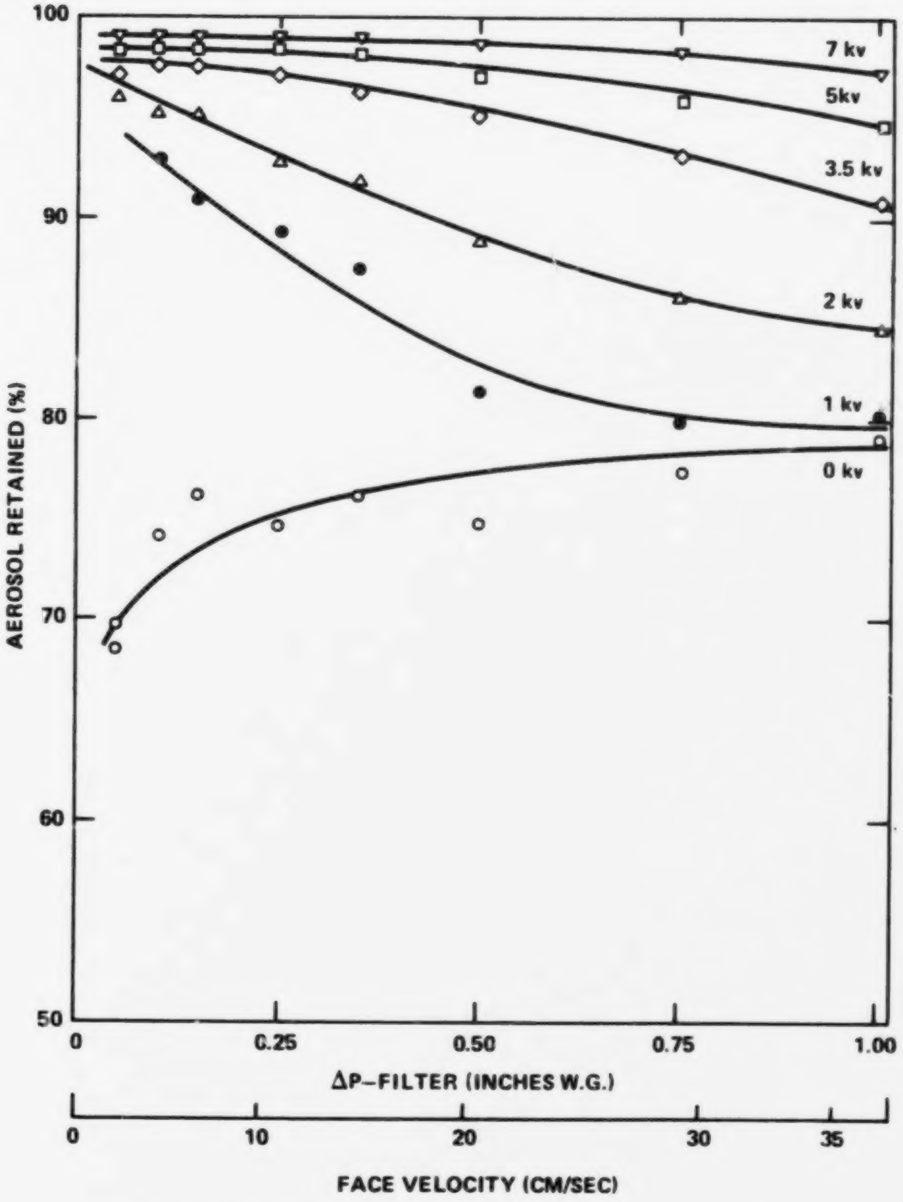

FIG. 5 INFLUENCE OF APPLIED VOLTAGE UPON RETENTION OF 0.3 MICRON DOP AEROSOL BY HP–200 FILTER MEDIUM

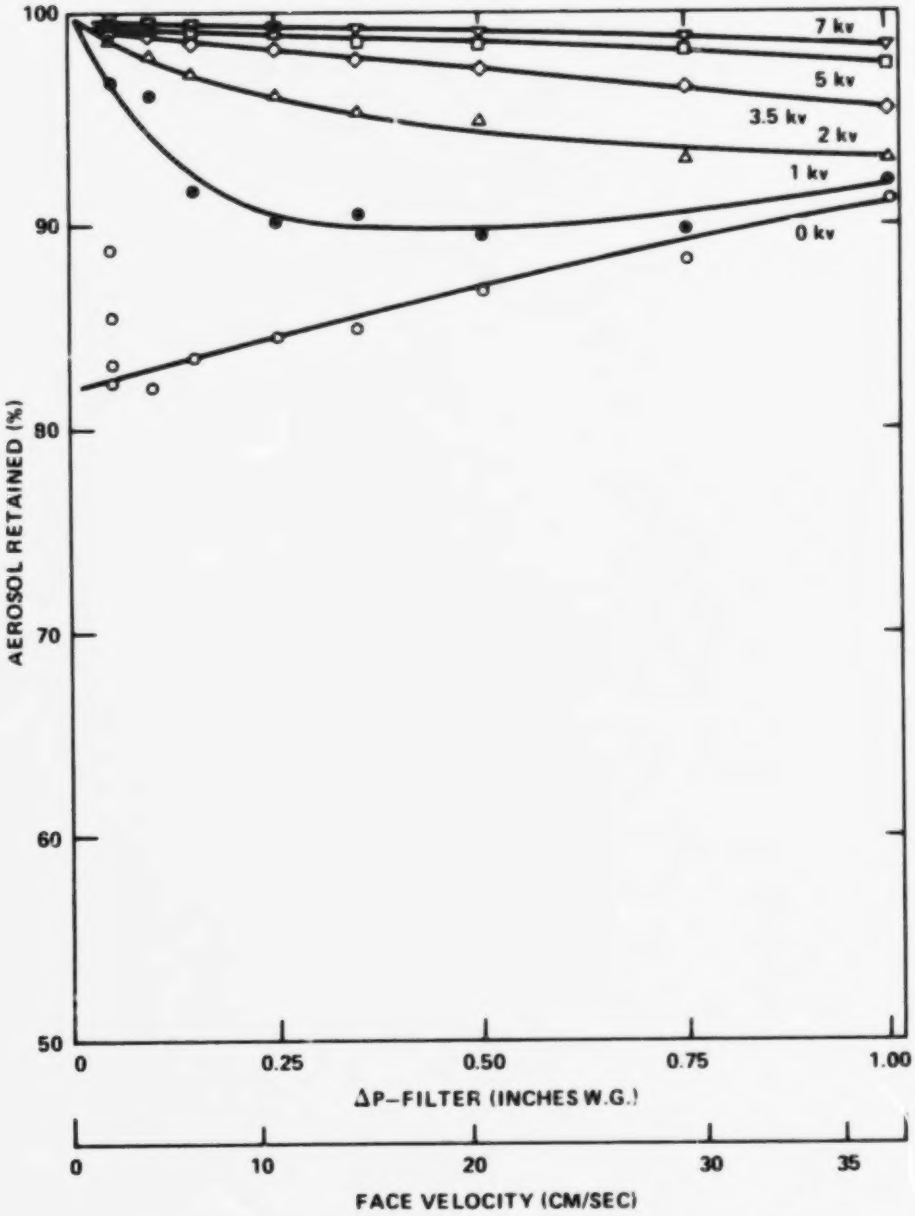

FIG. 6 INFLUENCE OF APPLIED VOLTAGE UPON RETENTION OF 1.0 MICRON DOP AEROSOL BY HP–200 FILTER MEDIUM

Calculated values of the DAF are presented in Tables II and III for Filter HP-15 challenged with 0.3 and 1.0 micron DOP, respectively. At the manufacturer's recommended flow rate of 44 cm/sec (0.35 in. pressure drop) and with 7 kn applied to the electrodes the DAF was 2 for 0.3 micron aerosol and 4 for 1.0 micron aerosol.

Table II

DIELECTROPHORETIC AUGMENTATION FACTOR AS A FUNCTION OF VOLTAGE AND AIR VELOCITY IN HP-15 FILTER MEDIUM; 0.3 MICRON DOP AEROSOL

Air Velocity cm/sec	Filter Voltage, kv			
	2	3.5	5	7
7	2	3	6	9
14	2	2	3	5
21	1	2	3	3
33	1	2	2	3
44	1	1	2	2
56	1	1	2	2

Table III

DIELECTROPHORETIC AUGMENTATION FACTOR AS A FUNCTION OF VOLTAGE AND AIR VELOCITY IN HP-15 FILTER MEDIUM; 1.0 MICRON DOP AEROSOL

Air Velocity cm/sec	Filter Voltage, kv			
	2	3.5	5	7
7	3	6	11	23
14	2	3	5	9
21	2	3	4	7
33	1	2	4	5
44	1	2	3	4
56	1	2	2	3

The retention of 0.3 and 1.0 micron aerosols by Filter HP-100 is shown in Figures 3 and 4, respectively. The related DAF values are shown in Tables IV and V. Performance of this filter was

Table IV

DIELECTROPHORETIC AUGMENTATION FACTOR AS A FUNCTION OF VOLTAGE AND AIR SPEED IN HP-100 MEDIUM; 0.3 MICRON DOP AEROSOL.

Air Speed, cm/sec	Filter Voltage, kv 2	3.5	5	7
3	8	19	95	330
6	3	13	39	120
9	3	11	28	100
15	2	6	13	42
20	2	5	9	27
28	2	4	6	14
39	2	3	4	9
50	1	2	3	6

Table V

DIELECTROPHORETIC AUGMENTATION FACTOR AS A FUNCTION OF VOLTAGE AND AIR SPEED IN HP-100 MEDIUM; 1.0 MICRON DOP AEROSOL

Air Speed, cm/sec	Filter Voltage, kv 2	3.5	5	7
3	30	110	300	1100
6	6	30	95	360
9	4	18	50	170
15	3	10	20	50
20	2	6	13	35
28	2	4	8	18
39	2	3	5	11
50	1	2	3	7

qualitatively similar to that of HP-15, but the efficiency was higher throughout. Again, the dielectrophoretic effect was greatest at the low flow rates and decreased as velocity increased. From Tables IV and V one can interpolate a value of the DAF for the manufacturer's recommended flow rate of 20 cm/sec (0.40 in. pressure drop). At this flow rate and with an applied voltage of 7 kv the DAF is 21 for 0.3 micron aerosol and 28 for 1.0 micron aerosol.

The retention of 0.3 and 1.0 micron aerosols by Filter HP-200 is shown in Figures 5 and 6 respectively. HP-200 was the most efficient filter of the three tested. Still, the augmentation effect of the electric field was quite significant. At the manufacturer's recommended flow rate of 17 cm/sec (0.40 in. pressure drop) and with an applied voltage of 7 kv the DAF interpolated from Tables VI and VII is 19 for 0.3 micron aerosol and 30 for 1.0 micron aerosol.

Table VI

DIELECTROPHORETIC AUGMENTATION FACTOR AS A FUNCTION
OF VOLTAGE AND AIR VELOCITY IN HP-200 FILTER MEDIUM;
0.3 MICRON DOP AEROSOL.

Air Velocity, cm/sec	Filter Voltage, kv 1	2	3.5	5	7
2	5	8	11	18	28
4	4	5	12	15	22
6	3	5	10	15	22
11	2	4	9	16	24
15	2	3	7	13	20
21	1	2	5	10	18
29	1	2	3	6	13
37	1	1	2	4	8

Table VII

DIELECTROPHORETIC AUGMENTATION FACTOR AS A FUNCTION
OF VOLTAGE AND AIR VELOCITY IN HP-200 FILTER MEDIUM;
1.0 MICRON DOP AEROSOL

Air Velocity cm/sec	Filter Voltage, kv 1	2	3.5	5	7
2	6	26	66	127	380
4	5	11	34	65	138
6	2	7	21	43	50
11	2	5	12	23	37
15	2	4	10	19	43
21	1	3	6	13	26
29	1	2	4	7	18
37	1	1	2	4	8

The relative improvement in filtration performance due to the applied electric field was notably greater for the HP-100 filter than for the HP-15. The HP-100 blend contains more fine fibers than the HP-15 and is more densely constructed. This would have offered more opportunity for dielectrophoresis to occur, all other things being equal. In terms of the DAF, the relative improvement shown by Filter HP-100 was about the same as that shown by Filter HP-200 at their respective rated flow conditions. Because of differences in initial filtration efficiency, the relative improvement caused by dielectrophoresis was greater at low flow rates for Filter HP-100 than for Filter HP-200.

The possible effect of charged aerosol particles has not been addressed in this study. If any aerosol particles had been inadvertently charged, the filtration improvement attributed here entirely to dielectrophoresis would have been due in part to coulombic forces.

Conclusions

Application of an electric field through a glass fiber dust filter medium effects a substantial improvement in filtration efficiency by means of dielectrophoresis. Further work was required to learn the most effective conditions of air flow rate, fiber blend, density, and applied voltage. Further investigations were also needed to test the applicability of dielectrophoresis to filter media other than glass fiber and to aerosols other than DOP.

NRL - NAVSURFWPNCEN Experiments

To obtain a broader and more realistic picture of the dielectrophoretic effect in air filtration, studies were made (see Figures 7 - 10) using a standard fly ash supplied by EPA as aerosol. The aerosol differences are fundamental: liquid to solid, spherical particles to those of irregular shape, uniform particle size to a wide size distribution, and a substantial increase in material density. The handling and analytical problems derived from these changes are difficult and are not yet fully solved so that the data are not as precise as desired.

Figure 11 shows the dielectrophoretic performance of the HP-100 medium when challenged by fly ash at various voltages and air speeds. The location of the characteristic curve for zero voltage remains in some doubt. The DAF's shown in Table III are therefore based on the individual points for zero voltage rather than on an assumed curve. In general the DAF's for the fly ash are at least as large as those obtained for the same filter with the 1.0 micron DOP aerosol.

Tables VIII - XI show the percent penetration of several filter media by the Detroit fly ash aerosol under various conditions. Tables XII - XV give the corresponding dielectrophoretic augmentation factors (DAF's). The DAF is the penetration at zero voltage divided by the penetration at the voltage of interest. Table XVI shows the effect of ion-trapping the aerosol, and suggests that our present ultrasonic aerosol generator causes a very undesirable degree of charging of the aerosol particles.

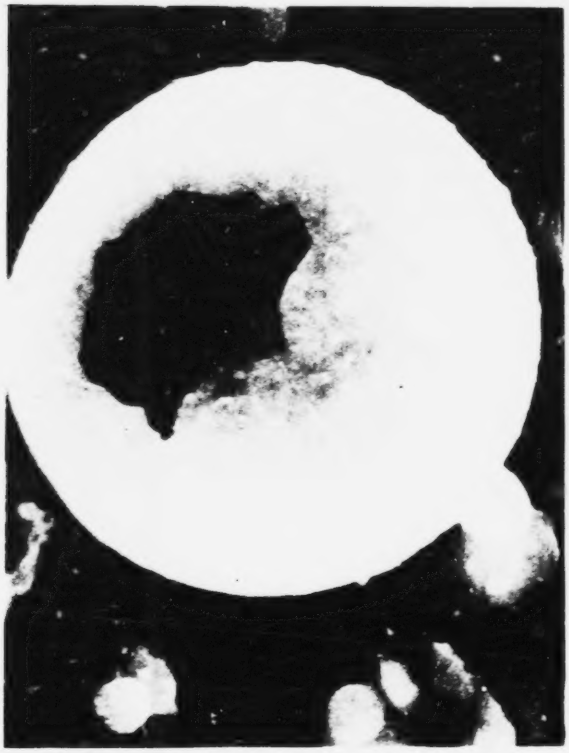

FIG. 7 STANDARD FLY-ASH–10,000X, AREA A

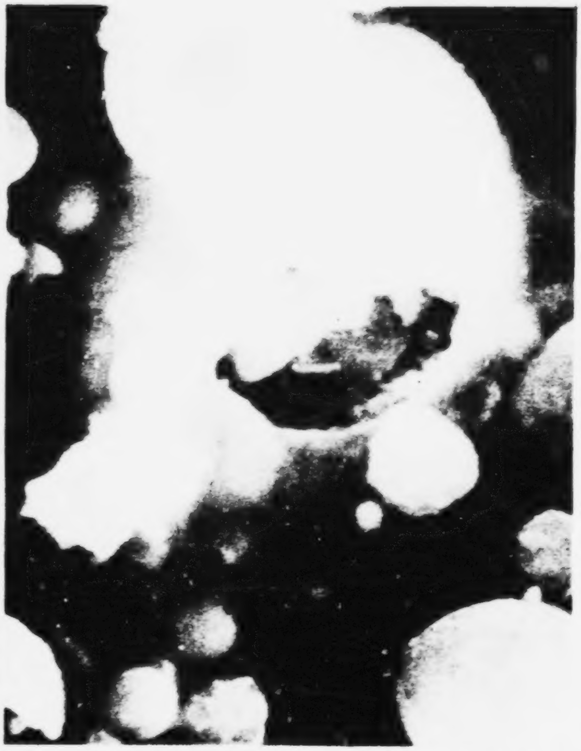

FIG. 8 STANDARD FLY-ASH–10,000X, AREA B

FIG. 9 STANDARD FLY-ASH–5,000X, AREA C

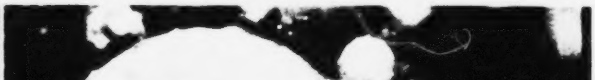

FIG. 10 STANDARD FLY ASH–5,000X, AREA D

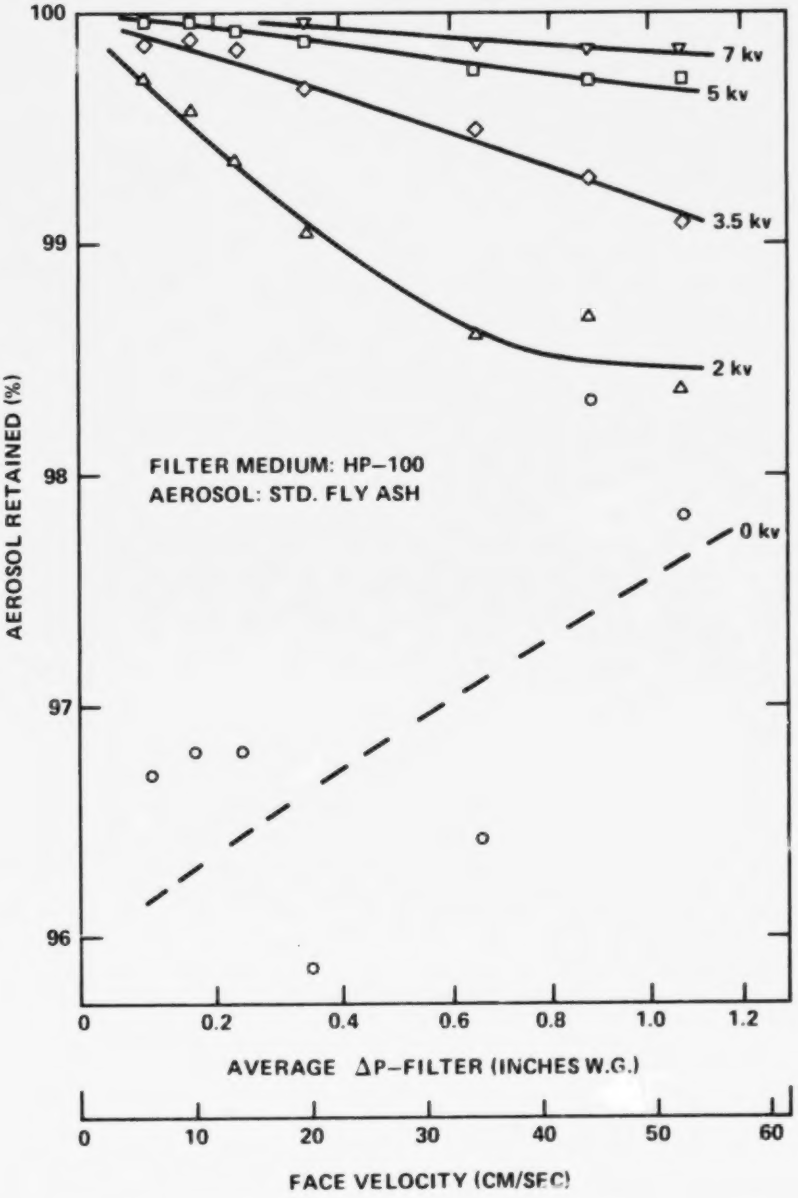

FIG. 11 INFLUENCE OF APPLIED VOLTAGE UPON RETENTION OF STANDARD FLY ASH BY HP–100

Table VIII

PENETRATION OF HP-100 FILTER MEDIUM BY FLY ASH AEROSOL

Air Velocity, cm/sec	Percent Penetration at 0Kv	2Kv	3.5Kv	5Kv	7Kv
6	3.4	0.28	0.12	0.086	--
10	3.2	0.42	0.11	0.042	--
14	3.2	0.65	0.15	0.084	--
20	4.1	0.97	0.34	0.19	0.057
35	3.1	1.4	0.52	0.25	0.16
45	2.3	1.4	0.71	0.34	0.17
53	3.2	1.7	0.90	0.32	0.18

Table IX

PENETRATION OF HP-15 FILTER MEDIUM BY FLY ASH AEROSOL

Air Velocity, cm/sec	Percent Penetration at 0Kv	2Kv	3.5Kv	5Kv	7Kv
20	9.8	3.0	0.68	0.58	0.29
35	5.3	3.0	1.2	0.78	0.58
45	4.3	3.2	1.4	0.70	0.85
53	6.4	3.3	2.3	1.3	1.3

Table X

PENETRATION OF POLYURETHANE FOAM BY FLY ASH AEROSOL

Air Velocity, cm/sec	Percent Penetration at Kv		.5Kv		.0Kv	
	1L.*	2L.*	1L.	2L.	1L.	2L.
14	62.0	52.2	9.8	4.2	4.8	1.7
20	57.4	46.0	13.5	5.8	6.4	2.5
35	53.4	43.1	15.4	8.1	10.1	4.6
45	40.5	28.9	22.8	10.7	12.4	5.7
53	34.2	27.8	23.2	14.4	16.9	7.5

* 1 layer * 2 layers

Table XI

PENETRATION OF RIGIDIZED VINYL-GLASS FILTER MEDIUM BY FLY ASH AEROSOL

Air Velocity, cm/sec	0Kv	3.5Kv	7.0Kv
14	57.6	10.2	3.8
20	59.8	11.8	4.8
35	50.0	14.3	9.5
45	34.0	17.9	10.7
53	39.9	22.3	11.4

Table XII

DIELECTROPHORETIC AUGMENTATION FACTOR FOR FILTRATION OF FLY ASH AEROSOL BY HP-100 FILTER MEDIUM

Air Velocity cm/sec	DAP at:			
	2Kv	3.5Kv	5Kv	7Kv
6	12.1	28.3	39.5	--
10	7.6	28.9	75.7	--
14	4.9	21.0	37.6	--
20	4.2	12.0	21.5	71.9
35	2.2	6.0	12.4	19.3
45	1.6	3.2	6.7	13.4
53	1.9	3.6	10.0	17.8

Table XIII

DIELECTROPHORETIC AUGMENTATION FACTOR FOR FILTRATION OF FLY ASH AEROSOL BY HP-15 FILTER MEDIUM

Air Velocity, cm/sec	DAP at:			
	2Kv	3.5Kv	5Kv	&kv
20	3.3	14.4	16.9	33.8
35	1.8	4.4	6.3	9.1
45	1.3	3.1	6.1	5.1
53	1.9	2.8	4.9	4.9

Table XIV

DIELECTROPHORETIC AUGMENTATION FACTOR FOR FILTRATION OF FLY ASH AEROSOL BY POLYURETHANE FOAM

Air Velocity, cm/sec	DAF at: .5KV 1 layer	DAF at: .5KV 2 layers	DAF at: Kv 1 layer	DAF at: Kv 2 layers
14	6.3	12.4	12.9	30.7
20	4.2	7.9	9.0	18.4
35	3.5	5.3	5.3	9.4
45	1.8	2.7	3.3	5.1
53	1.5	1.9	2.0	3.7

Table XV

DIELECTROPHORETIC AUGMENTATION FACTOR FOR FILTRATION OF FLY ASH AEROSOL BY RIGIDIZED VINYL-GLASS MEDIUM

Air Velocity, cm/sec	DAF at: 3.5Kv	DAF at: 7Kv
14	5.6	15.2
20	5.1	12.4
35	3.5	5.3
45	1.9	3.2
53	1.8	3.5

Table XVI

PENETRATION OF HF-100 FILTER MEDIUM BY FLY ASH AEROSOL, SHOWING DIELECTROPHORETIC AUGMENTATION FACTOR, WITH AND WITHOUT ION TRAPPING (AIR VELOCITY, 14 cm/sec)

Voltage, KV	With Ion Trapping Penetration, %	With Ion Trapping DAF	Without Ion Trapping Penetration, %	Without Ion Trapping DAF
0	9.4	--	3.2	--
2	3.4	2.8	0.65	4.9
3.5	1.5	6.4	0.15	21
5	1.1	8.9	0.084	38
7	0.43	22	--	--

Bill Yanta at White Oak made a number of runs to develop histograms of fly ash particle sizes with his Laser Doppler Velocimeter. They show the most numerous particle size upstream from the filters to be 1 to 1-1/4 microns. Using a foam filter, the downstream particle size is essentially the same. With the HP-100 medium, however, the histograms show peaks at about 0.3 and 1 micron and in some cases, still larger sizes.

Figures 12 and 13 show the experimental apparatus used by NRL and NAVSURFWPNCEN/WO in conducting the measurements. Figure 14 shows more detail of the Laser Doppler Velocimeter.

The NRL light-scattering technique performs very well, both in principle and in practice, with a largely monodisperse aerosol such as DOP. However, with polydispersed aerosols, such as fly ash, the smaller particles scatter light out of proportion to their mass. In our filtration studies with fly ash, the smaller particles tend to be more penetrating than the larger ones; therefore the concentration of particles downstream from the filter is exaggerated, and the indicated filter effectiveness is less than if measurements were made on a weight basis. On the other hand there are counter-balancing factors: there is a greater loss of the larger fly ash particles in the sampling process and due to interception by the screen electrodes. Therefore, considerable work remains to be done to improve the precision and accuracy of dielectrophoretic filtration measurements with fly ash.

Conclusions

We have found extremely promising degrees of dielectrophoretic augmentation with all of the filter media we have studied: the three glass fiber media (HP-15, HP-100, and HP-200); the polyurethane foam, and the rigidized milti-layer vinyl-coated glass screening.

We believe that the experimental results so far, together with logical projection, strongly suggest a whole family of dielectrophoretic air filter media, with considerable range of characteristics, which will allow some major steps forward in a variety of air filtration applications. We know of only one substantial drawback to dielectrophoretic air filtration, and that is the possibility of a high voltage spark between the electrodes resulting in performation of the filter and ignition of the accumulated dust. Consequently, we have given a lot of thought on how this drawback can be reduced or eliminated. Several promising concepts have arisen for not only eliminating sparks but also allowing operation at higher voltages. Another concept allows dielectrophoretic operation with no power supply at all. NRL has filed for patent applications on this.

Proposals for follow-on work have been presented directly to NERC-RTP by NRL.

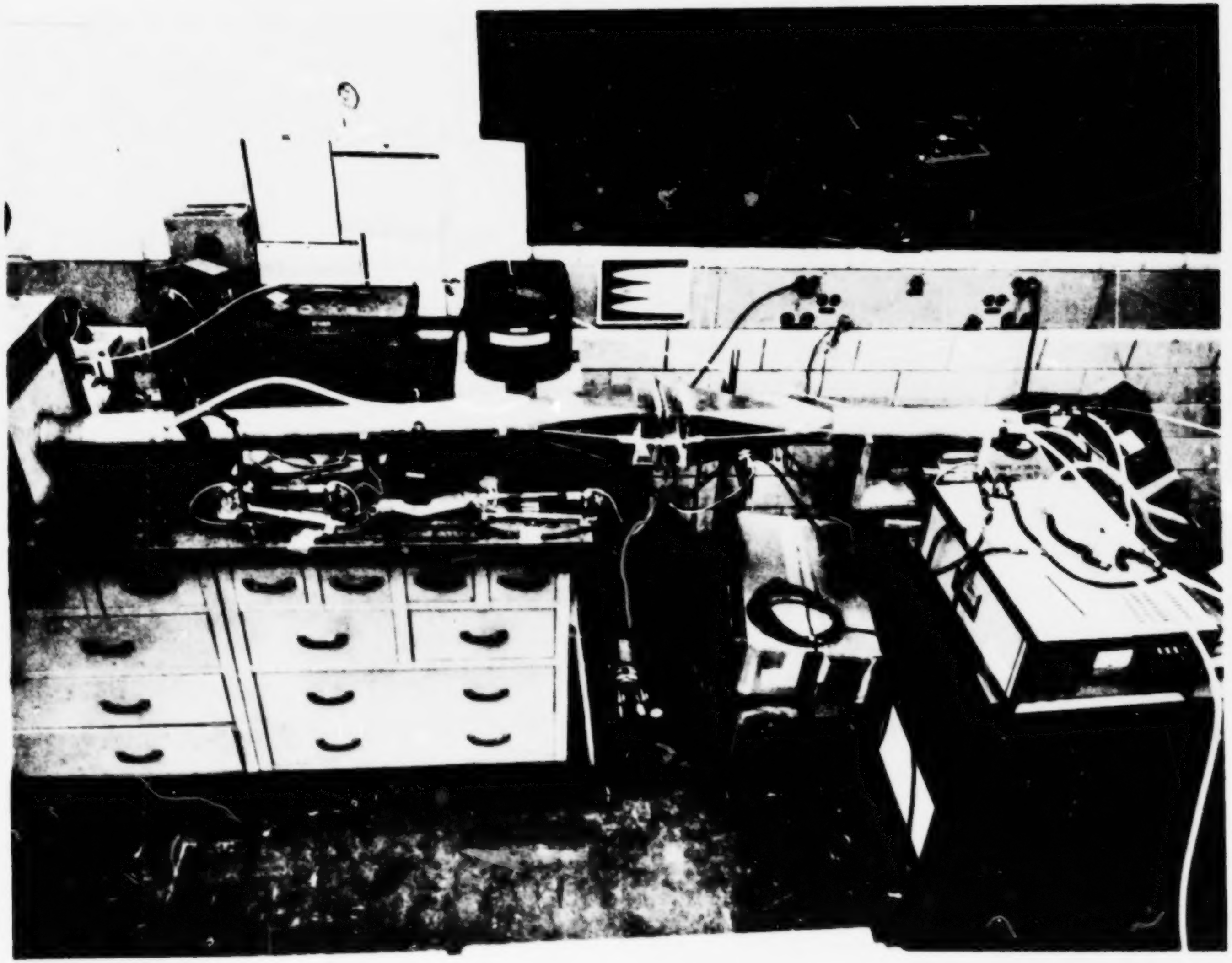

FIG. 12 EXPERIMENTAL CONFIGURATION OF WIND TUNNEL AND FILTER ARRANGEMENT

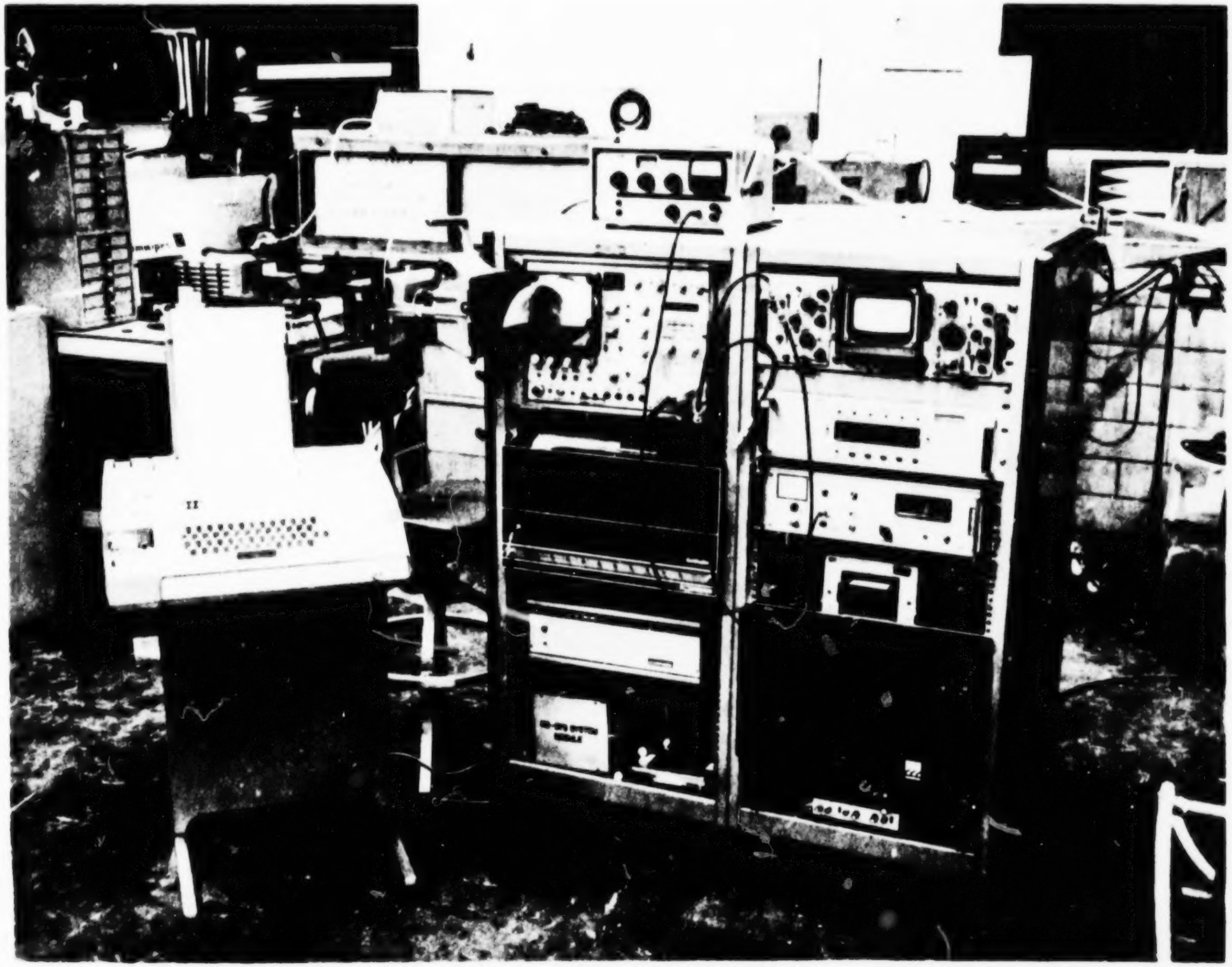

FIG. 13 DATA PROCESSING UNITS FOR FILTER EVALUATION

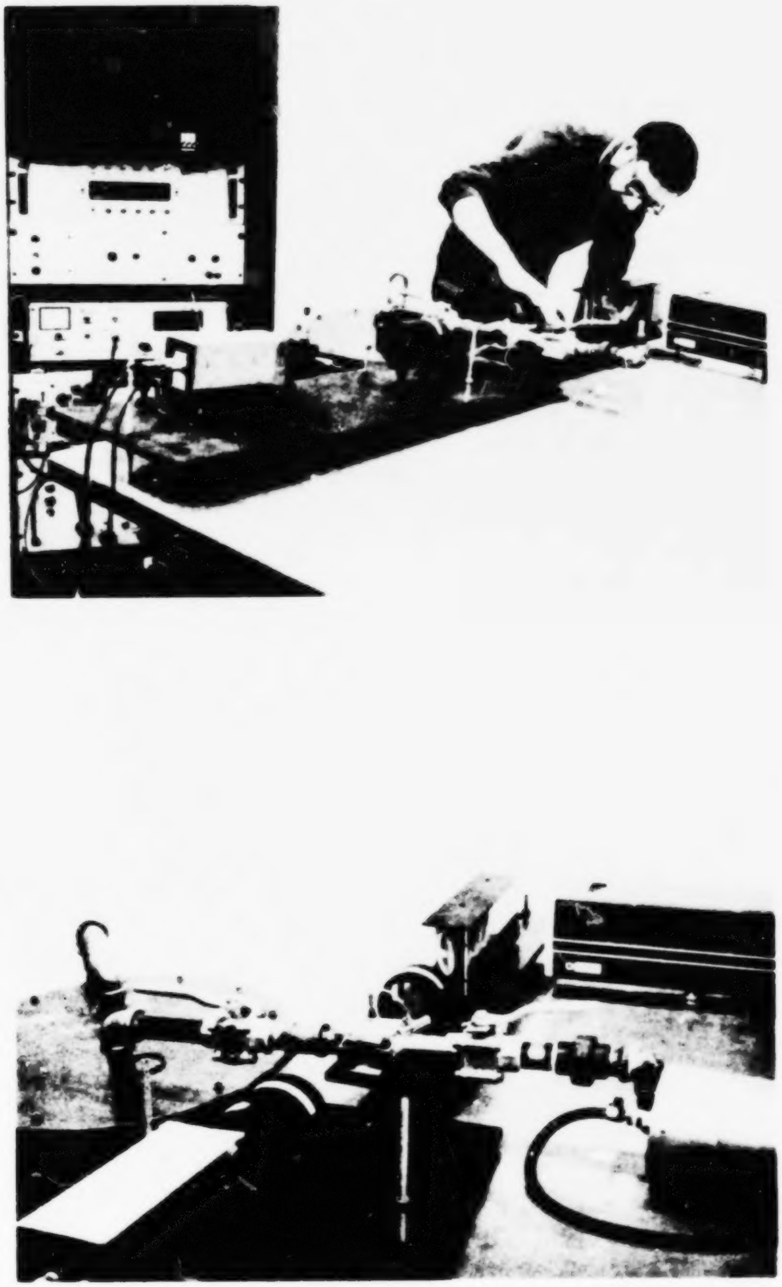

FIG. 14 DETAILS AEROSOL WIND TUNNEL USING LASER DOPPLER VELOCIMETER

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16. ABSTRACT
The report condenses an effort designed to identify and transfer significant technology concerned with air pollution monitoring and control from the Department of Defense (DOD) to the EPA. Included are technology profiles of each DOD laboratory involved in particular work of interest to EPA's Industrial Environmental Research Laboratory-RTP, a bibliography of pertinent DOD documentation, and a description and assessment of how the study was conducted.

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